The Fourth R (Second Edition)

David Moursund

This second edition contains the entire first edition and about 30 percent new content has been added. The first edition was published in December, 2016 and has had a combined total of more than 18,000 page-views and downloads. All links have been checked and updated where needed. Additions include a new chapter (Chapter 5) and a new appendix (Appendix 8).

For readers who want to "cut to the chase," I suggest you go directly to Chapter 1. In brief summary, it discusses a **4th R** of **R**easoning/Computational Thinking that uses the combined powers of human brains and artificially intelligent computer "brains" to help solve problems and accomplish tasks. For a review of basic aspects of problem solving, see Appendix 1.

The **4th R** is both a *content area* and a *general-purpose tool* useful throughout all areas of human endeavor. Like the **3 Rs** of **R**eading, '**R**iting, and '**R**ithmetic, the **4th R** of **R**easoning/Computational Thinking is foundational in a modern education.

The **4th R** has already been integrated into the informal education of the daily lives of a great many children, especially in the economically developed nations of the world. We know that children begin to explore and use the **4 Rs** in their infancy, and the use of Information and Communication Technology (ICT) is now commonplace in schools and homes. However, we are making slow progress in thoroughly integrating the **4th R** into the everyday and all-day school curriculum at a level commensurate with the emphasis we place on the first **3 Rs**.

Read this Second Edition at http://iae-pedia.org/The_Fourth_R_(Second_Edition). Download the Microsoft Word file from http://i-a-e.org/downloads/free-ebooks-by-dave-moursund/307-the-fourth-r-second-edition.html. Download the PDF file from http://i-a-e.org/downloads/free-ebooks-by-dave-moursund/308-the-fourth-r-second-edition-1.html.

Read the First Edition at http://iae-pedia.org/The_Fourth_R. Download the Microsoft Word file from http://i-a-e.org/downloads/free-ebooks-by-dave-moursund/289-the-fourth-r/file.html. Download the PDF file from http://i-a-e.org/downloads/free-ebooks-by-dave-moursund/290-the-fourth-r-1/file.html.

Publisher: Information Age Education: Eugene, Oregon, USA. See http://iae-pedia.org/Main_Page#IAE_in_a_Nutshell.

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Front Matter

David Moursund, Author

David Moursund is an Emeritus Professor of Education at the University of Oregon. His professional career includes founding the International Society for Technology in Education (ISTE) in 1979, serving as ISTE's executive officer for 19 years, and establishing ISTE's flagship publication, *Learning and Leading with Technology,* now published by ISTE as *Empowered Learner*.

He was the major professor or co-major professor for 82 doctoral students. He has presented hundreds of professional talks and workshops throughout the world. He has authored or co-authored more than 60 academic books and hundreds of articles. Many of these books are available free online. See http://iae-pedia.org/David_Moursund_Books.

In 2007, Moursund founded **Information Age Education (IAE).** IAE provides free online educational materials via its *IAE-pedia, IAE Newsletter*, *IAE Blog,* and books. See http://iae-pedia.org/Main_Page#IAE_in_a_Nutshell.

In 2016, with the help of his son Russell Moursund and daughter-in-law Sonia Moursund, Moursund established **Advancement of Globally Appropriate Technology and Education (AGATE)** as a 501(c)(3) corporation designed to contain and expand Information Age Education (IAE). See http://agate.solutions/.

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Acknowledgements

Thanks to Ann Lathrop for her editing assistance.

Thanks to Ken Loge for his technical and publishing support.

IAE (Information Age Education)

Information Age Education (IAE) is a non-profit company in the state of Oregon founded in 2007 by David Moursund. Its goal is to help improve worldwide informal and formal education at all levels. IAE considers each person to be a lifelong learner and a lifelong teacher. Every interaction a person has with another person is both a learning and a teaching experience. (Just think of an infant child learning to cry when it wants something and how this trains a parent or caregiver!)

The educational systems of our world face the challenge of preparing students for lives in which humans and computer systems will increasingly work together to solve problems and accomplish tasks. The steadily improving capabilities of these computer systems means that our educational systems must be very flexible in order to accommodate both these advances in computer technology and the needs of humans in a rapidly changing world.

IAE continues to expand its wide variety of free online resources being developed to help in working toward meeting this challenge. The IAE Web pages have had a combination of more than 14 million page-views and downloads. Its current list of free resources and activities includes:

- Free *IAE-pedia*. See http://iae-pedia.org/index.php?title=Special:PopularPages&limit=250&offset=0.
- Free *IAE Newsletter* published twice a month. See http://iae-pedia.org/IAE_Newsletter.
- Free *IAE Blog.* See http://iae-pedia.org/IAE_Blog.
- Free books published by IAE. See http://iae-pedia.org/David_Moursund_Books; http://iae-pedia.org/IAE_Newsletter#Free_IAE_Books_by_David_Moursund_and_Robert_Sylwester; and http://iae-pedia.org/Robert_Albrecht#Free_Books_by_Bob_Albrecht.
- Other IAE documents. See http://i-a-e.org/downloads.html.

AGATE (Advancement of Globally Appropriate Technology and Education)

Advancement of Globally Appropriate Technology and Education (AGATE) was founded in 2016 by David Moursund, Russell Moursund, and Sonia Moursund. AGATE is a 501(c)(3) corporation whose purpose is to continue and expand the work of Information Age Education (IAE). AGATE has somewhat broader goals than IAE. I like to think of AGATE as working to improve quality of life throughout the world by use of appropriate education and technology.

Here is a useful analogy that helps to describe the work of AGATE. Think about a village having a "wise" man or woman who serves as a fount of information, knowledge, and wisdom. Now provide this wise person with connectivity to people and information resources throughout the world. Then think about the implications of partially supplanting that wise person with access to artificially intelligent computer systems that are growing steadily more intelligent.

The wise woman has human knowledge and skills. The computer system–which may well be a robot–has a different kind of knowledge and skills. Each has strengths and weaknesses. Working together in solving problems and accomplishing tasks, they can surpass either working alone.

This is a worldwide challenge. The worldwide education-related research that has been done in the past and/or is now underway needs to be appropriately interpreted, disseminated, and used to help improve education across the entire world. AGATE's goal is to expand the current work of IAE to accomplish this task. See http://agate.solutions/.

Part 1: Chapters About the 4th R

Preface to Part 1

> "The whole people must take upon themselves the education of the whole people and be willing to bear the expenses of it. There should not be a district of one mile square, without a school in it, not founded by a charitable individual, but maintained at the public expense of the people themselves."(John Adams; American statesman and Founding Father who served as the first Vice President (1789–1797) and second President of the United States (1797–1801); 1735-1826.)

> "The purpose of education, finally, is to create in a person the ability to look at the world for him/herself." (James Baldwin; American novelist, playwright, and civil rights activist; 1924-1987.)

Here is a question to get you started in learning from this book, "What did you learn during the past 24 hours?" Ponder the question for a minute before reading this short section from an *IAE Newsletter,* Learning 24 Hours a Day (Moursund, 3/15/2018):

> You have probably heard the derogatory order, "Get your brain in gear." Actually, it is a rather silly statement. Your brain does not have any gears; however, it functions 24 hours a day. Equally important, it is always learning, both day and night. The electrochemical processes going on in your brain don't stop just because you are asleep.

> I recently asked myself the question, "What did I learn during the past 24 hours?" It turned out that I was not able to give a very good answer. However, the question got my brain in gear. I began by thinking about the idea that I need to learn a lot every day just to stay even, since I do a lot of forgetting every day. For those who like to deal with difficult brain questions, does the information disappear, or is it just not retrievable because the connections/pathways to it have become so weak?

> I had certainly done a lot of reading during the previous 24 hours, both recreational and "scholarly, academic." I played my two favorite computer games, caught up on my email, watched two good television programs on a Public Broadcasting channel, talked with some people, and spent a good part of the day at my computer working on research and current writing projects. Also, I spent time at my gym as well as time enjoying watching children and dogs playing on the beach. The question remained, "What did I learn during these 24 hours of my life?"

I hope this "exercise" has made you think because, when you are thinking, you are exercising your brain and learning. Now, back to a more traditional Preface.

This Book

Part 1 of this short book is based on six *IAE Newsletters* published during late 2016 and early 2017. The Preface and six chapters are about changing education to include a **4th R** of **R**easoning/Computational Thinking. These chapters are slightly revised versions of the six newsletters. Part 2 provides some supplementary materials from nine *IAE Blog* entries and other sources.

The book's intended audience is preservice and inservice teachers at the PreK-12 levels, as well as all people interested in improving education at these levels. The emphasis is on defining and securing widespread acceptance of the addition of a **4th R** to the traditional list of the **3 Rs** of **R**eading, '**R**iting, and '**R**ithmetic.

The **4th R** is named **R**easoning, and it stands for Computational Thinking. **R**easoning/Computational Thinking makes use of one's brain and Information and Communication Technology (ICT), and especially Artificial Intelligence, to represent and solve problems. I strongly recommend that this **4th R** of **R**easoning/Computational Thinking should be thoroughly integrated into the traditional **3 Rs**.

Part 1 presents a rationale for this thorough integration of the **4th R** throughout the curriculum and in all aspects of preservice and inservice teacher education. It assumes that all readers of this book are familiar with the **3 Rs** that have formed the foundational content of schooling for more than 5,000 years. These **3 Rs** are both important disciplines of study in their own right, and also very important components of the various disciplines that make up PreK-12 education.

I believe that a good education is a birthright of all children. This point of view has been strongly supported by the United Nations (UN) since its inception (United Nations, 1948). The 1948 United Nations Declaration of Human Rights states in Article 26:

> (1) Everyone has the right to education. Education shall be free, at least in the elementary and fundamental stages. Elementary education shall be compulsory. Technical and professional education shall be made generally available and higher education shall be equally accessible to all on the basis of merit.
>
> (2) Education shall be directed to the full development of the human personality and to the strengthening of respect for human rights and fundamental freedoms. It shall promote understanding, tolerance and friendship among all nations, racial or religious groups, and shall further the activities of the United Nations for the maintenance of peace.
>
> (3) Parents have a prior right to choose the kind of education that shall be given to their children.

Education still remains one of the UN's highest priorities. Quoting from the UN Secretary General (Ki-moon, 5/19/2015):

> Education must do more than produce individuals who can read, write and count. It must nurture global citizens who can rise to the challenges of the twenty-first century. At any age, people can learn. Let us give them the chance, so that we can all create a new future.

Chapter 1 introduces the **4th R** of **R**easoning/Computational Thinking (Information and Communication Technology) as both a discipline of study in its own right and as a new fundamental component of the other disciplines that students study in PreK-12 education.

Chapter 2 presents Robert Branson's Upper Limit hypothesis that only a major paradigm shift, such as the extensive use of Information and Communication Technology in education, can propel our education results to new, higher levels.

Chapter 3 lists some of the problems our world faces in the 21st century. Information and Communication Technology is both a source of some of these problems and an aid to addressing many of them.

Chapter 4 proposes some approaches to improving education in order to help prepare students to become adults who have the knowledge and skills needed to help them to address the many major problems our world faces.

Chapter 5 considers the **4th R** as both an aid to learning and as an aid to making use of one's learning.

Chapter 6 outlines some of my personal philosophy of computers in education and encourages readers to develop and implement their own personal philosophy of computers in education.

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Chapter 1

Adding a 4th R to the 3 Rs of Education

Based on *IAE Newsletter:* Issue 198, November 30, 2016.
See http://i-a-e.org/newsletters/IAE-Newsletter-2016-198.html.

> "The only person who is educated is the one who has learned how to learn and change." (Carl Rogers; American psychologist; 1902-1987.)

> "Nothing could be more absurd than an experiment in which computers are placed in a classroom where nothing else is changed." (Seymour Papert; South African/American mathematician, computer scientist, and educator; 1928-2016.)

The **3 Rs** of **R**eading, '**R**iting, and '**R**ithmetic (math) in our schools today are both *disciplines of study* and *tools* that are useful across all curriculum areas. In the early 1970s, when computers began to be widely available, Art Luehrmann and other computer-oriented educational leaders strongly recommended that all students should become *Computer Literate* (Moursund, 2016b). Many suggested that all students should learn some computer programming and that all should learn to make effective use of some basic computer tools.

Clearly, Computer Science is an important discipline in its own right and computers are also a powerful aid to representing and solving problems throughout the curriculum. That is, Information and Communication Technology (ICT) is both a discipline of study and a broad-based tool, just as are the **3 Rs**.

More recently, the term *Computational Thinking* has come into common use (Moursund, 2016a). This term can be thought of as describing our current insights into Computer Literacy (Carnegie Mellon, n.d.). Quoting from this website:

> Computational Thinking is the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent.

The "information-processing agent" referred to here is typically a human, a computer (including robots) and/or some combination of the two. More broadly, we certainly want to include the brains of other living creatures. For example, a person using a guide dog is included in this definition.

The Wikipedia provides the definition:

> Computational Thinking (CT) is the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer–human or machine–can effectively carry out.

Pay careful attention to the emphasis on computer brains and human brains working together to solve problems and accomplish tasks. That is a unifying theme in this and subsequent chapters of the book.

Computational Thinking is a "mouthful" and it seems to me it would be difficult to convince our educational systems that all students should be learning the **3 Rs** as well as Computational Thinking. Hmmm. How about learning the **3 Rs** and Computational **R**easoning? **Aha! A 4th R!** However, I thought, why make use of a new term (computational reasoning) when the term computational thinking is already in wide use. Hence, I decided on the terminology **R**easoning/Computational Thinking for the **4th R**.

Many people have thought about adding a **4th R** to the traditional **3 Rs** of **R**eading, '**R**iting, and '**R**ithmetic. My 6/24/2018 Google search of the expression *4Rs in education* produced about 124,000 results. Considerable browsing led me to the conclusion that people writing about a **4th R** in education tended to be interested in variations of **R**esponsibility, **R**espect, **R**esourcefulness, **R**esponsiveness, and **R**eligion. All of these suggested additions to the **3 Rs** miss the point that each of the **3 Rs** is both a discipline of study and a **fundamental cognitive tool** that useful in all disciplines of study.

A 2011 blog written by Cathy Davidson used the term *algo**R**ithm* for a **4th R** (Davidson, 2011). Quoting from her article:

> Here's a definition of Algorithm adapted from the Wikipedia dictionary. "Algorithm: A process or set of rules to be followed in calculations or other problem-solving operations, esp. by a computer." Algorithms are the basis for **computational thinking**, programming, writing code, and webcraft. Just as the last century saw a major educational initiative aimed at basic literacy and numeracy for the masses, the 21st century should be pushing for basic **computational literacy** for everyone, starting with kids and, of course, with adult and lifelong learning possibilities for all of us. [Bold added for emphasis.]

Continuing to quote Cathy Davidson:

> Here's some of what the fourth "R" of "algorithms" adds to the standard syllabus of 21st century learning. I'm sure others can add more:
>
> Algorithms and algorithmic thinking give kids of the 21st century the ability to write software and change programs to suit themselves, their own creativity, and their desire to self-publish their own multimedia work. Wonderful open source, nonprofit (free!) multimedia programs like Scratch inspire kids to learn and do, think and create, in moving images as well as text.

Davidson focuses mainly on the computer programming aspects of computers. The definition of the **4th R** that I use in my writings is considerably more broadly based. The remainder of this chapter and the rest of the book focus on my definition of the **4th R** of **R**easoning/Computational Thinking and its integration into the traditional **3 Rs**.

Information and Communication Technology (ICT)

Computer technology first became commercially available in the early 1950s. During the ensuing 65 years, the price-to-performance ratio of computer hardware has decreased by a factor of more than a billion. Moreover, computer software has been steadily improved. Today's PreK-12 students take for granted such things as computerized toys and games, Smartphones, the Internet and Web, robots, and artificial intelligence. Us "older folks" can compare the world of today's youth with the world we grew up in. In terms of ICT and other technology, a short summary is: **What a difference!**

We all recognize that not all of the change is for the better. Moreover, there are huge worldwide differences between the "haves" and the "have-nots" in terms of access to ICT.

One such change that we have all seen is an increasing worldwide competition for employment and a major change in the nature of employment. The Industrial Age with its many industrial-manufacturing jobs is long past (Moursund, 4/30/2014). It isn't that we need and produce fewer such manufactured products. Rather, it's that highly automated factories require far fewer employees to produce the products.

The next section looks to the future and addresses the question, "What technological developments will have the greatest impact on our future?"

Artificial Intelligence Today

Here is a recent AI forecast from Kevin Kelly, the founding executive editor of *Wired* magazine, and a former editor/publisher of the *Whole Earth Review* (Kelly, 10/26/2016):

> By far, the greatest impact in the coming decades will be due to artificial intelligence [AI]. **It will equal or exceed the scale of changes brought about by the industrial revolution.** That revolution was ignited by our invention of artificial power–steam power, motors, electricity–which greatly amplified and extended the natural power of muscles. Up until then, the only way to make things was to employ animal or human muscle.
>
> Once we harnessed artificial power and delivered it as a commodity on a grid, we could build skyscrapers, railways, factories, and the entire world of modernity. This artificial power transformed everything in our lives, from business, to education, to the military, to science, and beyond.
>
> With the coming of artificial intelligence, we are going to repeat that revolution. Instead of merely harnessing 250 virtual horses as we speed down the highway in our car, we are going to add 250 virtual minds and make it a self-driving car.
>
> As we deliver this AI as a commodity on the grid so that anyone can purchase as much AI as they want, we will begin to cognify everything that we formerly electrified. **Cheap, ubiquitous, ever-improving AI will transform everything in our lives. It will be a second industrial revolution.** [Bold added for emphasis.]

Kelly emphasizes the steadily growing importance and capabilities of artificial intelligence. This is an area of research and development in which thousands of researchers are building on the previous research and development of their colleagues and earlier workers in this field. I like to think of a new AI-based tool as an aid to human capabilities than can be mass-produced and distributed quickly and widely.

It often requires only a modest amount of time and effort to learn to make effective use of such new tools. For example, consider natural language translation by computer. From time to time, I receive an email message written in a language that is foreign to me. I copy it, then paste it into a free service such as *Google Translate.* I get an immediate translation that typically serves my needs.

AI is different from "human" intelligence. Thus, humans and computers bring somewhat different cognitive abilities to solving problems and accomplishing tasks. Humans and computers working together can often out-perform either working alone.

From the Industrial Age to the Knowledge Age

In terms of education, ponder the following question, “If a computer can solve or greatly help in solving a problem, answering a question, or accomplishing a task, what do we want students to learn about dealing with that problem, question, or task?”

You are aware that the same type of question can be applied to the tools developed during the *Industrial Age*. We have had well over two hundred years to answer this question for steam engines and subsequent inventions such as: trains and steamships; electrical power, telegraph and telephone; radio and television; gas powered and electric powered cars; airplanes and space shuttles; and worldwide trade and travel. All of these except space travel were developed before electronic digital computers first became available.

Many argue that our current PreK-12 educational systems are still best described as *Industrial Age.* But the world has moved on. The *Information Age* officially began in 1956, when the number of white-collar jobs in the United States first exceeded the number of blue-collar jobs (Moursund, 2016c). In the *Information Age*, a steadily increasing proportion of employment involves working with data, information, knowledge, and so on.

Figure 1.1 presents Arthur C. Clarke’s Cognitive Understanding Scale (Clarke, n.d.). This chart is intended to suggest that it takes an increasing level of understanding and insight to move up the scale. I believe Clarke developed this scale as an aid to communicating about various levels of human insight and understanding. According to Clarke:

> The Information Age offers much to mankind, and I would like to think that we will rise to the challenges it presents. But it is vital to remember that information–in the sense of raw data–is not knowledge, that knowledge is not wisdom, and that wisdom is not foresight. But information is the first essential step to all of these.

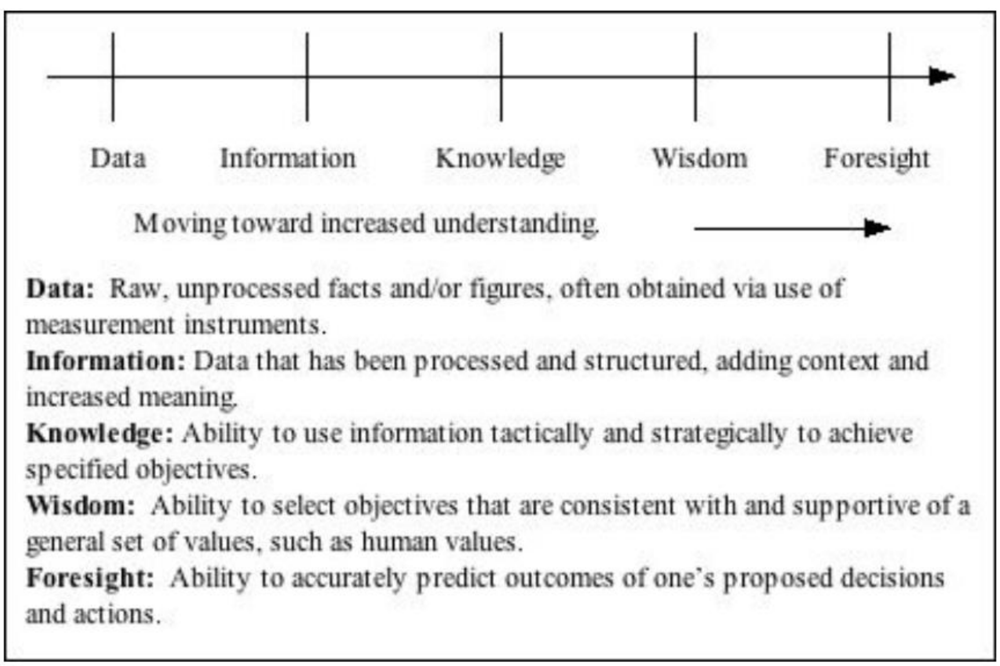

Figure 1.1. Arthur C. Clarke’s Cognitive Understanding Scale.

The first electronic digital computers were called data processing machines. They could take over many of the tasks of humans who used calculators and other aids to do data processing.

Soon it became clear that computers could store and process *information.* Indeed, the discipline of Computer Science began to be called Computer and Information Science.

This is an aside. If you want to stretch your brain a little, think about what it might mean to have a cognitive understanding of data and data processing. It might help to consider a child memorizing and following a step-by-step set of instructions to do addition, subtraction, multiplication, and division of integers. Even if the algorithms being used are memorized with little or no understanding, the child has some understanding of what it means to add numbers and to do other arithmetic.

The ability to add, subtract, multiply, and divide numbers is built or programmed into computers. A relatively inexpensive computer can carry out a billion calculations per second with no errors. But, the computer does not have even a child-like understanding of the meaning of these data processing tasks. Moreover, the computer does not "know" what problem is actually being solved. Is it processing a payroll, a day's receipts from sales by a chain of stores, or data from a scientific experiment?

In some sense, over the years, the performance of computers has moved up the Clarke scale. We are now at the level that computers are becoming somewhat adept at processing knowledge. However, even though Computer and Information Science has made considerable progress in Artificial Intelligence (Machine Intelligence), our current computer systems are quite weak in what we humans call cognitive understanding. While computers are becoming better and better in accomplishing tasks that humans use cognitive understanding to solve or attempt to solve, computers still use machine intelligence rather that human-like cognitive intelligence.

We are now well into the *Knowledge Age* that began in the early 1990s. Currently, there are huge disparities among the precollege educational systems of the world in terms of how well they are taking advantage of the technology and steadily accumulating human knowledge of this new *Knowledge Age* (Moursund, 2016c).

Educational Change Agents

The term *change agent* usually applies to a person who is trying to make a change in an organization. I use the term more broadly, as I include computers and other tools as change agents.

The *Knowledge Age* is building on the *Information Age*, which built on the *Industrial Age*, which built on the *Agricultural Age*, which built on the *Hunter-gatherer Age*. We currently have a vast range of physical and cognitive tools, and the combined capabilities of both are rapidly increasing. Robots provide an excellent example of combining *Industrial Age* machinery and *Knowledge Age* tools.

But wait, there's more! Consider the progress that is occurring in cognitive neuroscience, health and medicine, the behavioral sciences, and our understanding of how poverty, bullying, and social unrest affect learning. Also consider the fact that the world is facing a wide range of problems (Moursund, 11/30/2016). Many of these problems, such as population pressures, lack of fresh water, worldwide pandemics, and rising sea levels, are growing rapidly.

I hope it is clear to you that our educational systems need to appropriately accommodate the growing host of change agents, and that these change agents are themselves rapidly changing. I believe that the foundations of a good modern education now lie in the **4 Rs** described at the beginning of this chapter. It is very important to keep in mind that the **4th R** of **R**easoning/Computational Thinking strongly impacts the first **3 Rs**.

Integrating the 4th R into Education

An obvious challenge to integrating the **4th R** into education is the cost of the needed hardware, software, and connectivity. But, the economically developed nations are well along in meeting that challenge. The cost is modest relative to the total costs of education in these economically developed nations.

ICT is changing the first **3 Rs**. Let's use writing, one of the current **3 Rs**, as an example. We have long included the use of graphic images as part of writing for books, magazines, and journal articles. But, "ordinary" people could not take a photograph and integrate it into their written letters and other writings. Now, children can easily accomplish this task of adding images as they write using a computer. Indeed, they can easily make use of video in their "written" communications.

Many schools have stopped teaching cursive handwriting. (This is certainly displeasing to many of today's adults!) Students learn to print by hand, and they learn to write using a word processor. In writing using a word processor, one can readily take advantage of aids such as spelling and grammar checkers, a wide variety of typefaces and sizes, nicely formatted tables of data, and so on. So, our educational systems now face the challenge of teaching topics such as design, layout, use of various fonts, and use of graphics in desktop publication. Moreover, when writing for online publication, one can also make use of touch sensitive buttons and other links. This is another huge educational challenge, one that is certainly not beyond the learning capabilities of even relatively young students.

Nowadays, tables and collections of data are generated using spreadsheet and database software. However, it is by no means easy to learn to make effective use of spreadsheets and databases. These are powerful aids to representing and solving a wide range of problems, and many people skilled in their uses make their living applying such knowledge and skills. So, this constitutes another challenge to implementing the new **4th R.**

You can see the gist of this conversation. The **4th R**–which includes all aspects of the discipline of Information and Communication Technology (ICT)–is both a major area of study in its own right and is a powerful change agent in each of the traditional **3 Rs** (Moursund, 2016a).

The huge educational challenge will be to fully integrate ICT capabilities and uses into the teaching, learning, and use of the current **3 Rs**. As students begin to learn the conventional **3 R**s starting in PreK or earlier, the **4th R** comes into play. Their teachers need to be familiar with the appropriate roles of ICT throughout the PreK curriculum as well as in the everyday life of students outside of school. Curriculum content, instructional processes, and assessment all need to change to reflect students learning to make routine use of the **4th R** in each of the first **3 Rs**.

This challenge applies to teachers at all grade levels. We expect teachers at all levels and in all subject areas to have an appropriate level of reading, writing, and arithmetic knowledge and skills. By the time a person obtains teacher certification, that person has been studying and making use of reading, writing, and arithmetic for about 17 or 18 years of schooling (kindergarten through a bachelor's or master's degree). The task of bringing all current teachers and all new teachers up to this same level of **4th R** knowledge is indeed daunting!

ICT-based Aids to Learning the 4 Rs and Other Curriculum Content

The development of reading, writing, and arithmetic created a need for formal schooling and certainly changed the world. During the more than 5,000 years since these tools were first developed, our educational systems have gradually become better at teaching the **3 Rs**. However, this progress seems to have nearly plateaued perhaps 20 years ago. This is discussed in more detail in chapter 2.

Through the work of Benjamin Bloom and others, we have long known that a knowledgeable and skilled individual tutor is a powerful aid to learning (Moursund, August/September, 2000). For many years, educators have been working on developing computer-assisted learning systems that incorporate some of the characteristics of an individual tutor.

Here is a challenging topic to ponder. Once a student learns the basics of reading, writing, and arithmetic, why does this person require additional years of formal schooling in order to advance his or her education? What is there about having students coming together in a school, with classes of 20 to 30 or more students in a class, that is superior to just providing students with books? Thomas Edison touched on this question more than a hundred years ago:

> "Books will soon be obsolete in the schools.... Scholars will soon be able to instruct through the eye. It is possible to touch every branch of human knowledge with the motion picture." (Thomas A. Edison; American inventor and businessman; quotation from 1913; 1847–1931.)

We now have a growing number of *Highly Interactive, Intelligent Computer-assisted Learning (HIICAL)* systems. While these have not yet reached the level of highly skilled individual tutors, they have surpassed many of the skills of teachers working with classes of 20 to 40 or more students (Moursund, 9/11/2011). We can look forward to the time that HIICAL-based units of instruction and full courses span the curriculum. Learning to learn from HIICAL systems is a key component of a modern education.

We also have a growing number of Massive Open Online Courses (MOOCs). These multimedia online courses are typically designed both to present audio/visual information online and to involve student interactions online. While originally developed for use in higher education, they are seeing increasing use at the precollege level (Harrsch, 4/15/2018; Harrsch, 4/30/2018).

MOOCs can be quite expensive to develop. A 2017 report provides the estimate that "One hour of ready online course costs $7,140-35,550 ($21,345 on average) to produce"

(Raccoon Gang, 6/8/2017). This information might be helpful in making an estimate of the cost of developing a full-length MOOC.

For the most part, however, these MOOCs still do not meet my vision of being high-quality HIICAL. They tend to not provide the level of individualization that I think of as constituting HIICAL .

Remember that HIICAL is steadily improving. Also, HIICAL systems can make use of information stored on the Web, voice input, voice output, computerized language translation, and so on. HIICAL typically requires students to read online and/or offline materials, in addition to using the online presentations and demonstrations. Thus, typically such a course can be thought of as combining books with video in an interactive manner. Thus, a modern version Thomas Edison's forecast about books might say:

> "Students above the grade school level coming together in large grade-level groups taught by a grade-level teacher will soon be obsolete. Instead, students will learn through HIICAL appropriate to their previous educational attainments, and at both time and places fitting the individual needs of students and their caregivers."

Good HIICAL systems are both tutor and tool. That is, the software needed in a good HIICAL system can solve or help to solve a very wide range of problems. This is a key idea, so let's carry it a little further. We are used to the idea of *learning to read* and then *reading to learn*. We are also used to the idea of the Web as a gigantic online library that can help in solving a very wide range of problems. Thus, think of the Web as both a tool and an aid to learning, much as we think of learning to read and then reading to learn. Combining access to HIICAL with access to information on the Web can offer students an excellent online learning experience.

Final Remarks

We are well along in moving from the *Information Age* into the *Knowledge Age*. In the future, artificial intelligence and other computer-based aids to posing, representing, and solving problems will greatly supplement the physical and cognitive capabilities of humans. This ongoing change will require corresponding changes to all levels of our educational systems.

Our educational systems can be greatly improved by the thorough integration of the newly defined and expanded **4 Rs** of **R**eading, '**R**iting, '**R**ithmetic, and **R**easoning/Computational Thinking. Our educational systems will also be improved by integrating the routine use of HIICAL into the curriculum at all levels.

I suspect that most people do not understand the magnitude of the staff development challenges faced by current teachers and the changes that will need to occur in our preservice teacher education programs. Our current educational systems are based on curriculum content, pedagogical processes, and assessment that are thoroughly intertwined with a **3 Rs**-based educational system, one that largely ignores the **4th R**.

The **4th R** greatly adds to and changes the current **3 Rs**. In addition, it is both a large content area in its own right, and it is a major change agent in curriculum, instruction, and assessment. I believe the **4th R** will produce more change in education than all of the changes we have seen since the current **3 Rs** became such a powerful force in our educational systems when the first schools were developed about 5,000 years ago.

The magnitude of this challenge suggests that we need a major change in preservice and inservice education. The task of being a professional teacher must include substantially more time and resources for staff development than our schools currently provide. Learning on the job must become a much larger part of being a professional teacher.

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Chapter 2

Upper Limits of Education

Based on I*AE Newsletter:* Issue 195, October 15, 2016.
See http://i-a-e.org/newsletters/IAE-Newsletter-2016-195.html.

> "It isn't enough just to learn–one must learn how to learn, how to learn without classrooms, without teachers, without textbooks. Learn, in short, how to think and analyze and decide and discover and create." (Michael Bassis; American educator and author; 1946-.)

More than ten years ago, I read and later wrote about Robert K. Branson's article, Why Schools Can't Improve: The Upper Limit Hypothesis (Branson, Fall, 1987). In brief summary, Branson's article (now 30 years old) presents the case that, in 1987, schools in the U.S. were about as good as they were likely to become without the use of the new computer technologies that were emerging. For more information, see my paper, Developing a Philosophy of Computers in Education (Moursund, 2006; Moursund, 2/16/2013).

Quoting from Branson's1987 article:

> The first purpose of this paper is to question whether there is a significant discrepancy between the current levels of productivity and quality of American schools and the levels required to serve the society well. The second purpose questions whether the current approach, or the approaches of blue ribbon commissions are likely to produce significant improvements. A third purpose sets forth the hypothesis that the current school operations model cannot be improved by the recommendations offered by the National Commission. **The fourth purpose is to suggest that some form of technological intervention must be made before any substantial increases are made in productivity.** [Bold added for emphasis.]

Remember that this is a 1987 statement. The computer industry was well established by then. Many schools were making instructional uses of computers. However, the Smartphone and tablet computers were nearly 20 years in the future! You can get glimpses of computers in education at that time by reading my International Council for Computers in Education (ICCE) editorials from *The Computing Teacher* (Moursund, 1986-1987).

The quoted section uses the word *productivity* twice. Most of us don't think of a school as producing a product (educated children). Later in the article Branson explains:

> How well prepared is the graduate to meet employability requirements or succeed in additional schooling? Productivity refers to the relative achievement of students compared to the relative expenditures.

Throughout his article Branson uses test scores as a measure of productivity.

Branson's fourth point (bolded in the first quote) relates to the idea that Malcolm Gladwell called the *tipping point.* Gladwell's book, *The Tipping Point: How Little Things Can Make a Big Difference*, provides a number of examples of how changes in technology have produced tipping points that have caused many companies to go bankrupt (Gladwell, 2002). His key point is that new technologies often present a major challenge to companies that are doing well using the older technologies and ways of doing business. New and more nimble companies may well use newer technologies to capture customers served by the older, better-established companies.

Branson supported both research-based incremental improvements and the need for a paradigm shift. Quoting from Branson's later 2001 article (Branson, May, 2001):

> The conclusion to be presented and defended is that education cannot get better until it uses the results of programmatic research and development (R&D) to make incremental changes in the current processes. Educators cannot avoid the difficult and deliberate R&D work that other industries must do to make fundamental improvements.

Upper Limit Theory

Branson uses the word *hypothesis* in his 1987 article. I tend to use the term *theory* in discussing the same ideas. In a "pure" science, a theory (hypothesis) is proposed, and then scientists go about the task of trying to prove or disprove the theory. Their goal is to have results that are solid enough, sound enough, reliable enough (choose your own words) so that others can build on them with confidence. Newton's theory (laws) of motion published in 1687 was very useful, but eventually gave way to results from Einstein's general theory of relativity published in the early 1900s. Einstein's earth-shaking theory is still being tested now, more than a hundred years later.

My recent Google search of the expression *upper limit OR limits theory* produced more than 60 million results. (On 6/14/2018 the number of results was more than 98 million.)

The term *upper limit* is used in many different areas of performance. For example, how fast can a human run the 100-meter dash? The world record time for the 100-meter dash has decreased over the past hundred years from about 10.60 seconds to 9.58 seconds (Wikipedia, n.d.). This is due to some combination of a broader range of participants drawn from much of the world, better training, better shoes, better tracks, and so on. A "scientific" analysis of this data might suggest that 9 seconds is an upper limit.

Of course, with appropriate technology, it is quite easy for a person to travel 100-meters in less than 9 seconds. For example, today's automobile drag racers can cover a quarter mile in less than 4 seconds.

Figure 2.1 illustrates an incremental, *continuous improvement* model. Although the remainder of this chapter is specifically talking about education, the figure is applicable in many different areas of performance. Over a long period of time, incremental improvements are made. The effects are small from year to year, but they tend to occur in a cumulative manner. Thus, the total effect increases over the years.

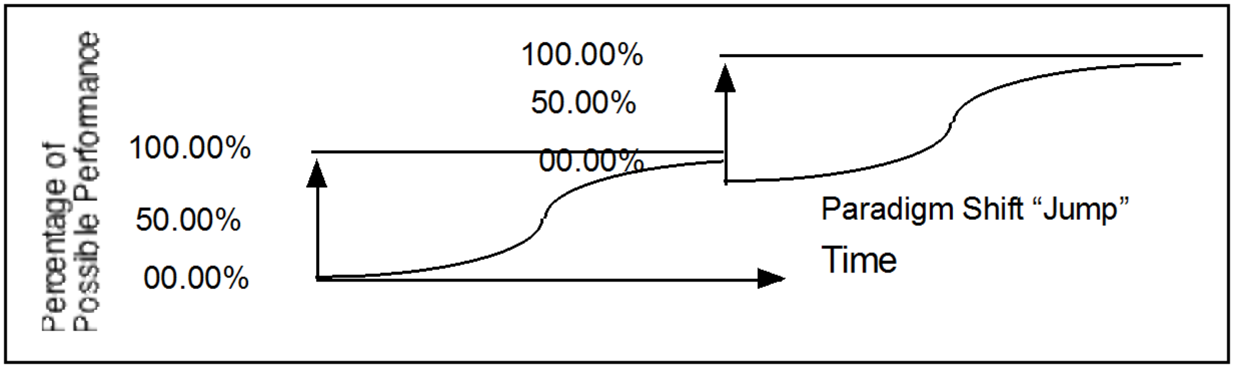

Figure 2.1. Continuous improvement model and upper limit theory.

Eventually, the new improvements begin to have a smaller and smaller overall effect. Whatever performance is being improved gets closer and closer to being as good as it can be–that is, unless there is a major breakthrough.

Our educational system employs a continuous, incremental improvement model. Now, 30 years since Branson's 1987 article, we can look back over a great many years of national data on K-12 education and see that little progress is occurring in the overall quality of student performance in areas such as reading, writing, science, and math. Branson argued that our educational system was performing at approximately the 95% level of possible performance by the mid-1960s. All of our efforts to improve our educational system since then have had little effect on performance in reading, writing, science, and math.

Branson's 1987 article argues that a paradigm shift–based on computer technology–would propel education to much higher levels of achievement. Figure 2.2 helps to illustrate the idea of a major paradigm shift. A paradigm shift is like starting anew from the level that has previously been achieved. Notice that in the graph given below, the new paradigm is shown starting below the achievement level of the previous paradigm. This is not unusual. It can take a long period of time to work out the "bugs" in the new paradigm in order for it to function efficiently. Full integration of the **4th R** would be a very major paradigm shift.

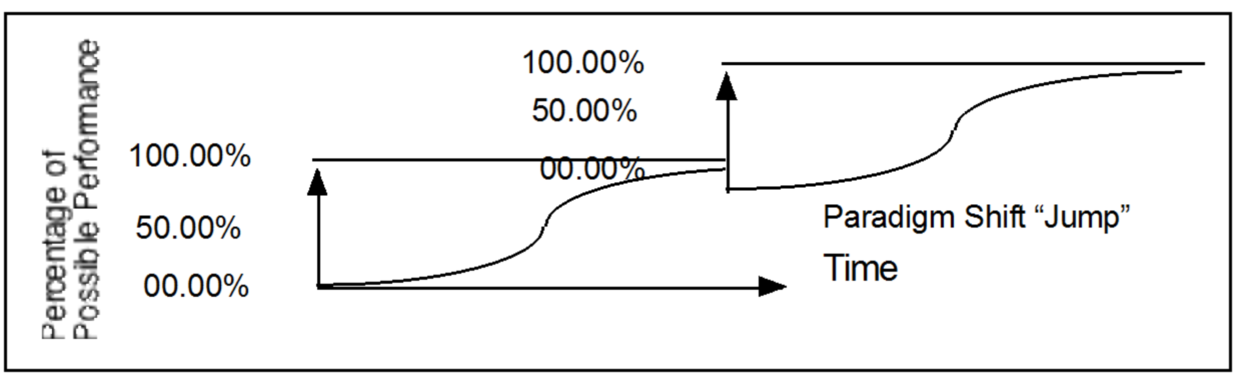

Figure 2.2. Paradigm shift, opening room for more incremental change.

Malcolm Gladwell's book provides examples of such paradigm shifts in business and industry. Here is a computer-related example. Before the invention of the transistor, vacuum tubes were an essential component of electronic equipment. Vacuum tubes (much like incandescent light bulbs) were relatively large, fragile, had a short life, and produced a great deal of heat. Such tubes were gradually improved over time since their invention in the early1900s. However, it seemed likely that they were approaching their upper limit in the 1940s, just as electronic digital computers were beginning to be developed.

The early computers were machines that used many thousands of vacuum tubes. In essence, the developing computer industry was stymied by the power consumption and heat of the best tubes that could be produced. You may find it both instructional and amusing to read a little bit about the 18,000 vacuum tube ENIAC computer built in the United States during 1943-45 (Computer History Museum, n.d.). Quoting from the museum site:

ENIAC lost one vacuum tube roughly every day or two. With almost 18,000 tubes, locating and replacing the failed one was challenging. Over time, however, the maintenance team developed the skill to fix a problem in just 15 minutes.

The invention and development of transistors was a tipping point–a major paradigm shift in electronics. Beginning after the invention of the transistor in 1947, vacuum tubes gave way to transistors. Now, just more than 70 years later, it may well be that you own a laptop or desktop computer that contains more than a billion transistors. Try to imagine such a machine containing a billion vacuum tubes, each the size of your thumb and each giving off 25 watts of heat. At 10 cents per kilowatt-hour of electricity, the hourly cost of running such a machine would be about $2.5 million! And, this does not include the cost of the needed air conditioning.

Perhaps you own a Smartphone. The newer Smartphone contains more than two billion transistors. The number of neurons in a human brain is estimated to be 86 to 100 billion. Intel now predicts that by 2026 they will be producing a computer chip containing as many transistors as the number of neurons in a human brain (Henderson, 1/6/2014). In June of 2017, IBM announced the development of a process to manufacture a chip containing 30 billion transistors (Nield, 6/6/2017).

How would you like to be a billionaire? The chances are that you own electronic equipment with transistors that are equivalent to several billion dollars' worth of vacuum tubes from the 1940s. In today's dollars, such vacuum tubes may have cost in the $5 to $10 range. So, a person who buys a modern Smartphone or tablet computer is buying the equivalent of billions of dollars' worth of the types of vacuum tubes that existed before transistors were invented. The transistor has led to paradigm shifts in many areas of human productivity.

Final Remarks

The 100-meter dash makes use of very precise measures of distance and time, and precise rules on drug use, equipment, track surfaces, wind speed, and so on. Thus, it is possible to compare performances among athletes throughout the world.

Our educational system lacks precision, both in what it is trying to accomplish and in how accomplishments are measured. If we stick to what can be measured by "standardized" tests, then we can compare results over time and in different locations. Even in this approach to trying to improve education, we need to take the results with a grain of sale. It has become common to teach to the test, including giving students lots of practice in taking these standardized tests. In essence, many schools set as a major goal to have their students perform well on certain types of tests. Personally, I don't believe that the major, overarching goals of education should be to prepare students to perform well on standardized test.

Our schools have considerable experience in measuring how well students at various grade levels can read, write, and do math. But, we do not have such data for the **4th R** of **R**easoning/Computational Thinking. **R**eading, '**R**iting, and '**R**ithmetic (math) are slowly changing areas. So, data gathered over the years tends to be useful in the near future. However, because the **4th R** depends on the use of technology that is changing rapidly, we cannot expect to currently develop school grade level performance measures that will stand the test of time.

We all know what modern electronic technology has done for the communication and entertainment industries. It seems like an understatement to say that electronic technology has revolutionized these industries. In addition, we routinely hear news about how robots are "taking over" middle class jobs. We are getting used to voice input to computers and voice output from computers (Weise, 9/29/2016).

Here is a very important "fact" to understand. Machine interfaces (the way that humans interact with the machines) are designed so that the machines are both relatively easy to learn to use as well as relatively easy to use. A typical five-year-old can learn to use a tablet computer, a Smartphone, a digital camera, and a wide variety of computer games. There is a strong parallel between this type of learning and the other informal learning that is going on for young children. **It is not school-based learning.**

Think of this from a formal schooling point of view. What can/do children learn from their routine, everyday lives outside of school? What do children learn from the 180 or so school days per year? Here are three questions for you to ponder:

1. How can the overall education of children be improved by modifications to their informal (outside of school) forms of education?
2. How can computer technology and other school-related paradigm shifts make school time more productive?
3. What should our informal and formal educational systems be doing to effectively deal with the continuing progress in artificial intelligence? Perhaps someday computers will be more intelligent than humans. Computer scientists call this the *singularity* (Moursund, 5/16/2015, 3/4/2015). This singularity would represent a paradigm shift in computer intelligence. Appendix 5 of this book contains more information about the (possible) coming singularity.

The first chapter also raised the question: If a computer can solve or greatly help in solving a problem, answering a question, or accomplishing a task, what do we want students to learn about dealing with the problem, question, or task? It would be a major paradigm shift to fully integrate the **4th R** into all of education. Perhaps it boggles your imagination to think of students having full access to online computers when taking tests.

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Chapter 3

We Face Many Local, National, and Global Problems

Based on *IAE Newsletter:* Issue 197, November 15, 2016.
See http://i-a-e.org/newsletters/IAE-Newsletter-2016-197.html.

> "The future is here. It's just not widely distributed yet." (William Gibson; American-Canadian writer who coined the term *cyberspace* in his short story Burning Chrome and later popularized the concept in his debut novel, *Neuromancer;* 1948-.)
>
> "The secret of change is to focus all of your energy, not on fighting the old, but on building the new." (Socrates; Greek philosopher; circa 469 BC-399 BC.)

Past, Present, and Future Problems

For a child, life is full of new things. That's just the way it is. For us adults who have been around for a number of years, each day brings some new things, but there is also a lot of "same-o, same-o."

We all know that today's children are tomorrow's adults, and so they need to be introduced to the major problems they will face as adults. Many of these problems are global. And, problem solving is a core component of each discipline that students study in school.

Each of the **4 Rs** is both a discipline of study and a tool useful across many other disciplines. The **4th R** of **R**easoning/Computational Thinking focuses on processing information. A computer is an information processing machine–a machine designed for the input, storage, processing, and output of information. One can form an analogy between a computer (brain) and a human brain. Thus, many researchers study the discipline of information processing both from the point of view of what human brains can do and what computer "brains" can do. What are the problem-solving capabilities and limitations of human brains and computer brains? Such a question is an important aspect of students learning and using the **4th R.**

This chapter lists and briefly discusses some of the global problems that I believe should be addressed in precollege education. This is not intended to be a comprehensive list. Rather, it is intended to illustrate the breadth and complexity of the world that we want our children to learn about.

One Historical Example

My father was born in 1901. Cars using internal combustion engines existed by then, but it was years before one first made it to his small town in Texas.

Think about some of the things you know about cars and trucks, gasoline and diesel fuel, highways, traffic accidents, and learning to be a safe and responsible driver. Think about the world's oil production and distribution systems, wars motivated by gaining or maintaining access to oil, air pollution, and so on. Suppose you were a teacher a hundred year ago, but you had relatively good foresight about what was to come in the world of ground transportation. You can ask the same question about ocean liners and airplanes. The internal combustion engine certainly was a world changer. Moreover, it was a change agent that cut across many areas of study and of everyday life. What would you have wanted your students to learn about this change agent?

Clearly, Information and Communication Technology (ICT) is a world changer. Like internal combustion engines, ICT is part of many different disciplines areas of study and everyday life. Where, in their schooling, should students be learning about these topics from an interdisciplinary, life-changing point of view? This is an aspect of the **4th R** that is often overlooked. Every teacher at every level has the responsibility of helping their students understand ICT as a change agent in the disciplines they teach.

World Problems

Carl Sagan was one of the great teachers and environmentalists of our time. I highly recommend that you spend the seven minutes that it takes to view his short video, We Speak for Earth (Sagan, 8/13/2015). At the same site, this short talk is followed by Carl Sagan's last Interview with Charlie Rose (Rose, 5/27/1996).

My 6/25/2018 Google search of the expression *world OR global problems* produced about 1,560,000,000 results. Needless to say, I did not read all of the articles! Many of these world problems have been with us for a long time and will continue for a long time. I find it interesting to look at lists prepared by different groups of people and at different times. There are considerable overlaps in the lists I examined. Here are a few sites that I enjoyed:

- A List of All Our Profiles on Global Problems (Centre for Effective Altruism, 2018).
- Fifteen Major Current Environmental Problems (CFF, n.d.).
- Global Issues Overview (United Nations, 2018). Also see Climate Change (United Nations, 11/16/2016).
- List of Environmental Issues. (Appropedia, 4/27/2018).
- Ten Most Critical Problems in the World Today (Loudenback, 2/26/2018).
- The Ten Biggest Problems in the World According to the European Union (Jardine, 10/7/2011). This article was written before Great Britain decided to withdraw from the European Union. However, the EU economic situation was number three in the list. Since this list is now seven years old, it provides a good example of persistent world problems.
- Top Ten Third World Problems (PEI Staff, 3/26/2015). In 2015, about 1/3 of the earth's population were living on less than $1.25 per day.

I built my own list, and I hope you will build a personal list. By "personal," I mean that items in your list are ones that you feel strongly enough about to be willing to expend some of your time, energy, and other resources to help address the problems. I strongly recommend that teachers work with their students to build both general-purpose lists of broad-based concerns they have as well as lists of concerns related to the specific subject areas that they are studying.

Part of Dave Moursund's List of Problem Situations

Here is part of my list, with the items in alphabetical order.

- Accountability and transparency at individual, corporate, organization, and government levels. (I want to know what "they" are doing for us and to us.)
- Addiction to use of computers for social networking and game playing. (This is a serious and growing problem.)
- Big and little brother and sister are watching you. (Privacy is rapidly disappearing. This problem has been greatly exacerbated by hackers stealing literally billions of records from various corporate and government records.)
- Climate change: global warming and changing weather patterns. (We humans have messed up the world's climate and weather, and now are trying to do something about this problem situation. It is difficult to achieve global collaboration in addressing this problem.)
- Cognitive neuroscience, especially as it applies to education and to quality of life. (What are the upsides and the downsides of research and its findings in this area?)
- Education for all, with special emphasis on worldwide education for disadvantaged people and women. (All people need an education that helps them to understand the types of problems on this list, how the problems affect them and their region of the world, and what they can do to help alleviate the problems.)
- Energy, with special emphasis on sustainable, non-polluting energy. (Will progress in science and technology substantially help in solving the world's energy problems?)
- Food, water, clothing, shelter, and other basics. (These are part of Abraham Maslow's hierarchy of needs. See McLeod, 2016).
- Fresh water. (Quoting from WWF, 2018: "Some 1.1 billion people worldwide lack adequate access to fresh water, and a total of 2.7 billion find water scarce for at least one month of the year. Inadequate sanitation is also a problem for 2.4 billion people–they are exposed to diseases, such as cholera and typhoid fever, and other water-borne illnesses.")
- Gender inequalities. (On average, throughout the world, gender inequality is decreasing. The world has a very long way to go before there is no discrimination based on gender.)
- Instructional uses of Information and Communication Technology (ICT). (This is a yin and yang situation discussed in detail in the subsequent chapters of this book. The world now has the technology and production capability to provide every person on earth with decent hardware, software, courseware, and connectivity.)
- Medical care. (How to provide all people with basic and more advanced medical care.)

- Population growth and an aging population. (The world population continues to increase, and the average worldwide life expectancy at birth is now increased to about 71 years.)
- Quality of life. (Related topics include poverty, jobs and decent-paying jobs, and huge economic inequalities. See appendix 3.)
- Racism and religious bigotry. (These contribute to terrorism at local levels; large-scale conflicts; refugee problems.)
- Shrinking world. (Think in terms of transportation, communication, and competition for jobs.)
- Sustainability and species extinction. (Continued growth in human population and conspicuous consumption are related topics.)
- Weapons of mass destruction. (While nuclear weapons are most frequently cited in this topic area, technology is making possible many other terrible threats, such as the development and spread of new diseases.)

If you have not already done so, I strongly recommend that you read appendix 1, Assessing and Teaching Creative Problem Solving. It defines and discusses the situation of "you, personally, have a problem." The definition includes the statement:

> **You have some ownership** (of the problem)–you are committed to using some of your own resources, such as your knowledge, skills, time, and energy, to achieve the desired final goal.

It is easy (and takes little time or thought) to scan a list of problem situations such as those in the list above. Many are likely to be familiar to you. You can be more or less concerned about each of the various problem situations, and you can add to the list. Many people find it easy to think in terms of the ubiquitous "they" having a problem or that "the world" has a problem. You, personally, may feel no commitment to helping "they" or "the world" to address these various problem situations.

I suggest that you pick out one or more problem situations that really concern you, either from those listed above or from your personal list. Then ask yourself what you personally are doing to help address the problems and what you think our schools should be teaching students about them. Pay special attention to possible roles of ICT in adding to and/or helping to diminish the problem.

I have selected two items from my list for further discussion in the remainder of this chapter.

#1: Climate Change

I live quite near the Pacific Ocean. A rising ocean, a massive earthquake, or a huge storm could devastate the region in which I live. The same can be said for 20 percent or so of the world's (human) population. I have no reason to believe that humans cause earthquakes along major fault lines, but I am absolutely convinced that humans are a major contributor to rising oceans and substantial changes in the weather.

While each of us can do a little to help, this is a global problem. I have found it interesting to follow the machinations of individuals, companies, nations, and the whole world as they have come to grips with the seriousness of this problem. I am quite concerned that, so far, we are doing "too little, too late."

The human race has survived and prospered through people learning to cooperate with each other in small groups, such as families, clans, and small tribes. We are not nearly so successful at city, state, national, and international levels.

It was pleasing to note that the Paris Accord on climate change received enough votes to go into effect beginning November 4, 2016 (United Nations, 11/4/2016). The recent United States decision to withdraw from the Paris Accord may seriously weaken this worldwide endeavor.

The world has had some successes in worldwide activities in the past. Examples include INTERPOL, a huge decrease in use of leaded gasoline, and remarkable progress in decreasing the size of the Antarctica ozone hole. Other examples include the Summer and Winter Olympics and a variety of other sports events. Global cooperation has certainly helped to facilitate travel between countries.

Formal and informal education, travel, and opportunities to get to know the "others" can all help. Schools provide an environment in which people from many different backgrounds can learn to work together toward common goals. Schools in the United States (and in many other parts of the world) have vast opportunities for improvement in such endeavors. In terms of Upper Limit Theory, we have by no means reached our upper limits.

One very powerful approach to problem solving is to break a big problem into smaller, more manageable pieces. Climate change, and many of the other global problems, lend themselves to actions by individuals and small groups at the local level. Perhaps the following quote comes to your mind, "Think globally, act locally." I believe such thinking should be thoroughly integrated into the education of our children.

#2. Quality of Life

Our world currently is making considerable progress in improving the average level of quality of life of its people. But, there are huge disparities. I see this all of the time where I live and as I travel. I am deeply saddened when I read about homeless and hungry school-age children in my city, state, and nation. I am constantly exposed to evidence of huge quality of life disparities throughout the world (see appendix 3).

Our world has the resources and capabilities to greatly improve the average quality of life of all of its people. Indeed, it has made considerable progress during the past century. This problem requires a combination of thinking and acting at the local community, city, state, nation, and international levels. There is plenty for all of us to do.

At a local school level, ponder these questions:

- Why should any children come to school hungry, without adequate clothing and school supplies, and/or having spent a night without adequate shelter?
- Why should any children leave school at the end of the day facing a night without appropriate food and shelter?
- Why should any children be fearful of serious bullying, injury, or death as they travel to and from school, spend time in school, or walk to a nearby store?

- Why should any students receive less than a good education due to inadequate school staffing, facilities, and supplies?

You may want to add to the list. Each of us can learn about problems in our own local community. Each of us can begin to think and act locally to help address such problems. And, each of us can support governments that are committed to addressing such problems at city, state, national, and global levels.

What You Can Do

Think about your current **4th R** knowledge and skills. How do they compare to your level of knowledge and skills in the other **3 Rs**? Discuss this same question with your students, children, colleagues, and so on. By doing so you will be contributing towards helping the **4th R** become an everyday component of the daily lives of yourself and others.

We all (children and adults) live in a world beset with large, serious problems. Education helps us to understand such problems, what is being done to address them, and what we personally might do to help to address them.

Each discipline of study addresses problems that help to define the discipline. Each discipline of study has developed tools and methods to help solve these discipline-specific problems. But, most problems of the world are interdisciplinary. Thus, it behooves every teacher to help students to learn both about the problems in the specific discipline being taught, and also how these relate to addressing problems in other disciplines.

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Chapter 4

Some Approaches to Improving Education

Based on *IAE Newsletter:* Issue 196, October 31, 2016.
See http://i-a-e.org/newsletters/IAE-Newsletter-2016-196.html.

> "The principal goal of education in the schools should be creating men and women who are capable of doing new things, not simply repeating what other generations have done." (Jean Piaget; Swiss philosopher, natural scientist, and educator, well known for his 4-stage theory of cognitive development; 1896-1980.)

Improving Our Schools

I often am annoyed when I hear someone say our school-based educational system is not as good as it should be, and then proceed to tell me one or more changes they believe should be made in order to improve it . I am reminded of the quote:

> "There is always an easy solution to every human problem–neat, plausible, and wrong." (Henry Louis "H.L." Mencken; American journalist, essayist, editor; 1880-1956.)

There are certainly a very large number of areas in which changes could be made. These changes might be made in goals, curriculum content, pedagogy, assessment, student and teacher safety while at school, textbooks and other curriculum materials, computer facilities, teacher education, teacher working conditions, teacher pay, school building facilities, class size, number of counselors and nurses available to students, school breakfast and lunch programs, reducing poverty, head-start programs, after-school programs, length of school day, starting time of the school day, number of school days in a year, and so on and so on. In terms of improving education, all of these are interrelated and any change affects different stakeholders (students, teachers, school administrators, parents, taxpayers, etc.) in different ways (Moursund & Sylwester, 6/15/2010).

The book you are now reading makes a strong case for the addition of a **4th R** of **R**easoning/Computational Thinking to the basic **3 Rs** of education. When I (and many others) make such a suggestion, I am aware of what H. L. Mencken said about easy, simple solutions to complex problems. I know that the **4th R** is neither a simple nor an easy solution. Rather, it represents a difficult, complex change that will take much effort over many years to implement.

As all of my readers know, **education is a very complex, multivariable endeavor**. Moreover, students and the world they live in are changing. For example, especially in the economically advanced nations of the world, almost all children grow up with Smartphones, Web and Internet access, social networking, and computer games. These outside-of-school experiences certainly have a significant educational impact on our students.

This chapter cannot explore each of the huge number of possible change areas. Many have been tried and not one has proven to be a "magic pill." Indeed, that is not surprising, since education is such a complex system. For example, you know that the education of a child begins even before birth. Children have learned a great deal before they begin to attend school. How will the proposed **4th R** changes accommodate the huge differences in young students entering a PreK-12 school system?

For practice, let us focus on just one possible area of school change–the goals of education (Moursund, 2/16/2013). Off the top of your head, pick one goal of education that you believe could/should be changed, and that the change would lead to an improvement in our educational system.

With that goal in mind, explore the following types of questions:

1. Can you, with confidence, name the current generally accepted goals of education in your country and school district? If you are going to propose a change, a good starting point might be to know the current goals. For a relatively stable and generally accepted set of national goals of education in the U.S., see Goals of Education in the United States (Moursund & Ricketts, 2016). Overarching goals include becoming career ready and/or college ready. These are mainly traditional goals that have stood the test of time. While schools certainly intend to prepare their students for the future, the traditional goals are not particularly future-oriented (Moursund, 2018).
2. Why did you select the particular goal you proposed to be changed? What evidence do you have that the changes you propose will actually improve achievement of the generally accepted set of goals? How would you measure the improvements?
3. How would you and others go about implementing the changes you propose? For example, will others support the changes, are the changes possible to implement, what will the changes cost, how long will the changes take, and so on?
4. What are some possible major flaws in the changes that you propose? Can you give good arguments both for and against your proposed changes?

You know that we each have our own ideas about effective goals for education. Our current educational system represents a compromise among a large number of stakeholder groups. This system has many and diverse goals, many ways of helping students to achieve these goals, and many ways to measure progress toward achieving goals. In total, as I have said repeatedly, education is a very complex and challenging human endeavor.

Consider just the issue of goal setting. People have their own ideas as to what constitutes a good education. Parents and other childcare providers each implement their own individual ideas as they care for and help to educate children. Teachers and other educators have their own ideas of what the goals should be, and how to implement them. Similar statements hold for the wide range of other stakeholders. In brief summary, setting goals, designing and implementing ways to achieve these goals, and measuring how well we are succeeding are not exact sciences. Education is not a factory-like manufacturing process.

Information Age and Knowledge Age

The *Information Age* in the United States began in 1956, when the number of white-collar jobs first exceeded the number of blue-collar jobs (Moursund, 2016a). The *Knowledge*

Age in the United States began in 1991, when the U.S. spending for information technology hardware and software first exceeded the spending for Industrial Age capital goods.

For background information, see the article Learning, Technology, and Education Reform in the Knowledge Age by Bernie Trilling and Paul Hood (Trilling & Hood, May-June, 1999). Figure 4.1 below is from Trilling and Hood's article. It lists seven key human concepts (components, activities) of the Knowledge Age. Some of these can be done without the use of computers, while others are done by computers and humans working together.

Seven C's	Component Skills
Critical Thinking-and-Doing	Problem-solving, Research, Analysis, Project Management, etc.
Creativity	New Knowledge Creation, "Best Fit" Design Solutions, Artful Storytelling, etc.
Collaboration	Compromise, Consensus, Community-building, etc.
Cross-cultural Understanding	Across Diverse Ethnic, Knowledge, and Organizational Cultures
Communication	Crafting Messages and Using Media Effectively
Computing	Effective Use of Electronic Information and Knowledge Tools
Career and Learning Self-reliance	Managing Change, Lifelong Learning, and Career Redefinition

Figure 4.1. The seven C's: Knowledge Age survival skills.

Spend some time reflecting on the components of this 1999 list of skills. Especially, look for components relating to the **4th R**. Do you think that our current PreK-12 educational systems are doing well in the Seven C's? Perhaps the skill of *Communication* seems particularly important to you. You have seen children sitting face-to-face in a group of two or more, each busy texting on a Smartphone. Some might be texting each other, but probably most are texting "friends" more remotely located. Hmm. They are certainly practicing the communication skill we call texting. I am amazed at the thumb dexterity I have seen in many texters. But, what about their face-to-face verbal communication skills? What about their writing skills?

Some of My Education-related Beliefs

I tend to think about improving education in very general terms. During my long career as a teacher and writer, I have developed a simple set of beliefs that have served me well in my educational endeavors. These beliefs help me to analyze and to understand both our current educational system and proposed changes in curriculum content, pedagogy, and assessment.

I believe:

1. A unifying purpose of education is to help people to improve the quality of their own lives and the lives of others.
2. Learning is a natural (inherent, built-in) ongoing and lifelong process for all people. Schooling should stress both learning to learn and becoming an intrinsically motivated and independent learner. Remember the quote given earlier in this book:
3. "It isn't enough just to learn–one must learn how to learn, how to learn without classrooms, without teachers, without textbooks. Learn, in short, how to think and analyze and decide and discover and create." (Michael Bassis; American educator and author; 1946-.)
4. All people have the right to a lifetime of rich and varied informal and formal learning opportunities. Schooling should be designed to help each person to develop and use his or her cognitive, physical, social, and emotional skills.
5. Each person is unique. Thus, we should be cautious about designing and implementing curriculum content, pedagogy, and assessment processes and goals that "pretend" all students are nearly alike.
6. Problem solving is an underlying, unifying theme in all education. Through informal and formal education and experiences, people increase their abilities to solve the types of problems, accomplish the types of tasks, and make the "considered" decisions that are needed in their work, play, interactions with other people, and other aspects of their everyday lives.

You undoubtedly have your own set of education-related beliefs. Our beliefs tend to be embedded in how we teach and in our own personal approaches to learning. Moreover, both you and I are likely aware that our own personal beliefs do not provide enough detail to design a good educational system.

Problem Solving and Expertise

Of my five beliefs listed above, I have spent the most time and effort on problem solving (Moursund, 2014). Also see chapter 3 and appendix 1 of this book. Problems and problem solving include:

- Question situations: recognizing, posing, clarifying, and answering questions.
- Problem situations: recognizing, posing, clarifying, and solving problems.
- Task situations: recognizing, posing, clarifying, and accomplishing tasks.
- Decision situations: recognizing, posing, clarifying, and making good decisions.

- Using higher-order critical, creative, wise, and foresightful thinking to do all of the above. Often the results are shared, demonstrated, or used as a product, performance, or presentation.

Gaining an increased level of expertise in problem solving is an important goal in the study of any academic discipline. Continuing to quote from the reference above:

Each academic discipline or area of study can be defined by a combination of general things such as:

- **The types of problems, tasks, and activities it addresses.**
- Its accumulated accomplishments such as results, achievements, products, performances, scope, power, uses, impact other societies of the world, and so on.
- Its history, culture, and language, including notation and special vocabulary.
- Its methods of teaching, learning, assessment, and thinking. What it does to preserve and sustain its work and pass it on to future generations.
- **Its tools, methodologies, and types of evidence and arguments used in solving problems, accomplishing tasks, and recording and sharing accumulated results.**
- **The knowledge and skills that separate and distinguish among: a) a novice; b) a person who has a personally useful level of competence; c) a reasonably competent person, employable in the discipline; d) an expert; and e) a world-class expert.** [Bold added for emphasis.]

Thus, I believe that instruction in any area of study should be designed to help students move up an expertise scale such as the one given in Figure 4.2. I developed this scale many years ago and have found it quite useful in my teaching. I also find it useful as I observe myself while learning a new game or task (Moursund, 2016b).

It is a large step from being in the upper five percent to being the best or nearly best in the world in a particular area. People winning medals in the Olympics are certainly in the upper .000001 percent (in the world) in their event. It takes considerable natural ability and many thousands of hours of hard work to achieve at that level.

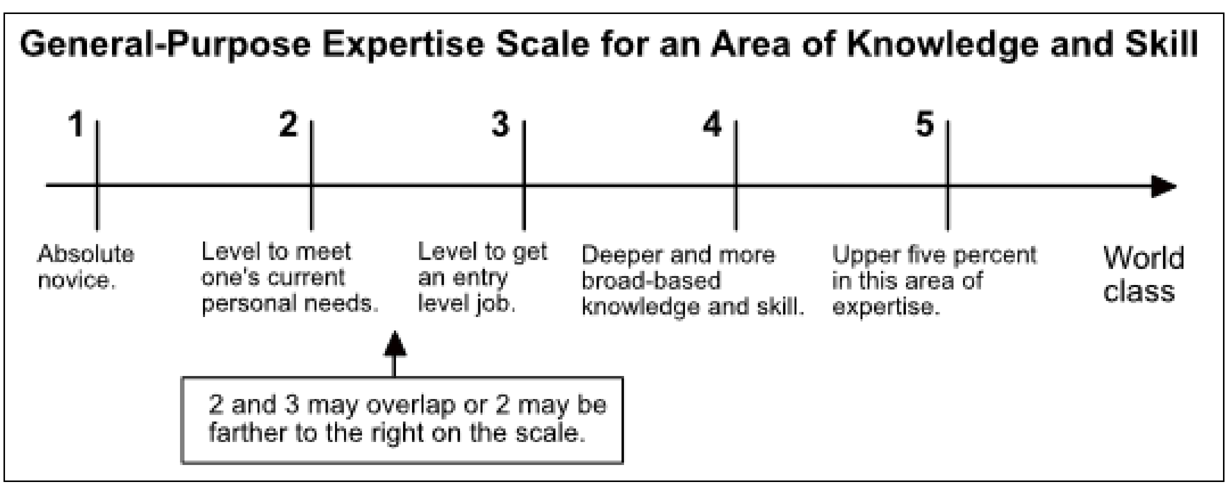

Figure 4.2. Expertise scale. It is not a uniform or linear scale.

Prehumans and humans have a three-million-year history of developing tools that aided them in solving problems and accomplishing tasks. Changes in our cognitive and physical capabilities, perhaps a hundred thousand years ago, provided us with the capabilities of large vocabulary and expressive speech. This communication "tool" was a major addition to human capabilities.

Much is known about how to help students gain increased expertise in problem solving. Moreover, problem solving can be taught in a manner that cuts across disciplines–a manner in which there is considerable transfer of learning, both from one discipline to another and over time. Thus, while my comments about problem solving do not suggest specific goals for the various disciplines of study, they provide one approach to measuring the overall quality of education of students. **How well can students apply their knowledge, skills, and readily available cognitive and physical aids to solving the problems they encounter in their lives?**

Final Remarks

Throughout the *Industrial Age*, people continued to learn better ways to design, mass produce, and mass distribute a wide variety of objects. They also developed and implemented the idea of education for the masses. The educational systems that we now have are a legacy of a mass production approach developed during the Industrial Age. They are based on educational goals and processes in content, pedagogy, and assessment that have evolved over the years to better accommodate changing needs of students and the world.

However, the current rates of change in education are not keeping up with changes in our world. The Industrial Age has given way to the *Information Age*, and in the United States and a number of other countries we now are in the *Knowledge Age*. The **4th R** is an essential component of this new Knowledge Age.

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Chapter 5

Learning to Do and *Doing to Learn*

Based on *IAE Newsletter:* Issue 201, January 15, 2017.
See http://i-a-e.org/newsletters/IAE-Newsletter-2017-201.html.

> "Once you have learned how to ask relevant and appropriate questions, you have learned how to learn and no one can keep you from learning whatever you want or need to know." (From *Teaching as a Subversive Activity* by Neil Postman and Charles Weingartner, 1969.)

Education has many goals. One of its fundamental and unifying goals is to help learners gain knowledge and skills that will be useful to them as they deal with problems and tasks they currently face or are likely to encounter in the future (Moursund, 4/19/2015). *Learning to learn* and *learning to make effective use of one's learning* cut across all disciplines of study.

I think of learning in terms of *Learning to Do* and then *Doing to Learn*. For example, students first *learn to read* and then they *read to learn.* This idea is fully integrated into our school system. In the United States, the expectation is that students will learn to read well enough by the end of the third grade so that reading across the curriculum can become a useful aid to their future learning across the curriculum. By the sixth or seventh grade, the general instructional plan is that more than half of school learning will come via reading.

Computer technology has greatly changed reading. Not only do we have interactive computerized reading materials, we also have greatly improved video aids to learning. In some sense, reading has expanded to be reading and using other visual aids to obtaining information.

This chapter considers the **4 Rs** of **R**eading, '**R**iting, '**R**ithmetic/math, and **R**easoning/Computational Thinking, and explores some of their *Doing to Learn* aspects. The goal is to help make schooling more relevant to students (Moursund, 8/7/2014).

Reading and Writing

In this section I explore *learning to read and write* and then *doing reading and writing* to gain greater skill in reading and writing.

Reading and writing are human inventions–tools that one can learn to use. Over thousands of years, people have worked on the task of how to effectively help children learn to read. Nowadays, parents and other child caregivers are strongly encouraged to start this instruction for infants, and to continue reading to and reading with their children up through elementary school. This one-on-one instruction by a loving parent or guardian is invaluable.

As children begin preschool, they receive group instruction in reading. For most students, group instruction provided by schools is reasonably effective, but not as effective as one-on-one instruction provided by a parent, caregiver, or tutor.

Instruction in writing may also be initiated at home by parents and other child caregivers. However, very young children lack the hand-eye coordination that writing using pencil/pen and paper requires. But wait! Now quite young children can access a tablet computer or child-oriented toy that has a keyboard. A keyboard overcomes the hand-eye coordination problem and facilitates very early learning of writing.

Interestingly, research on the use of a typewriter as an aid to learning reading and writing occurred in the 1930s (Wood & Freeman, 1932). Quoting from a master's degree thesis (Burke, 1939):

> Accordingly, the purpose of this study is to investigate with, with a teaching procedure which aims to establish correct fingering, the effects of the use of the typewriter on learning to read and write in second grade.

In this and other such studies, the learning results were positive. Notice the emphasis on keyboarding. As computers came into elementary schools, the keyboarding issue has been addressed by teaching *keyboarding*. You have undoubtedly seen students of all ages *texting* using a Smartphone. The ones who are fast at this keyboarding (now texting) task have taught themselves a two-thumb approach. I imagine that many typing teachers shudder with horror when they see this. I don't recall ever reading a published research article on teaching students this two-thumb method.

To summarize, a laptop, tablet computer, or educational toy a child is playing with can provide oral instruction and various types of feedback. While neither the same as a one-on-one human teacher, clearly we can now make use of components of the **4th R** at the preschool level to help a child get started in reading and writing. Teachers, even at the preschool level, now have growing numbers of children who have had this early computer-assisted instruction aid to learning reading and writing.

A learner progresses in *learning reading and writing* by *doing reading and writing.* An essential aid to this progress is feedback. The child can provide self-feedback. A child can be taught to ask, "Does what I have just read make sense to me? What does it actually mean to me?" Computer-assisted instruction can read individual words, sentences, or the whole passage to a learner, and can also provide feedback. Another very important aspect of feedback comes from discussing the just-read content with a parent, teacher, friend, or another person.

In summary, reading and writing are powerful aids to communication, writing, and thinking. Computers can now play a significant role in reading and writing instruction as well as in using one's reading and writing skills.

Arithmetic (Math)

To parallel the discussion of the previous section, I will use the vocabulary *learning to math* and *mathing to learn.* We all have personal experience in learning to do arithmetic and other aspects of mathematics. Math is a required component of schooling typically up through three years of high school math and continues to be required of many students even in the first year of their college undergraduate work. At all levels of instruction, teachers and their instructional materials attempt to include **uses** of the math they are teaching. **Math is taught both as a discipline in its own right and as a tool that is useful in doing things outside of the math classroom environment.**

My observation is that most math instruction is weak in the area of *mathing to learn* math and using math outside of the math classroom. Part of the difficulty is that "real world" applications of math tend to be above the math knowledge and skills a student has acquired by the time such challenges occur. For example, consider pie charts (circle graphs) that illustrate and make use of parts of a whole. These are visually and somewhat intuitive to second graders. But actually creating pie charts requires math content taught at the fourth and fifth grades. Contrast this with the ease of use of software designed for the task. A second grader can learn to use this software. The computer technology is used to invert the order of the traditional pie chart curriculum. My colleague James Fey developed the idea of an inverted curriculum in the early 1980s (Fey, 1984; Moursund, 1/11/2015).

Learning 4th R Tools and Using 4th R Tools to Learn

The dichotomy of *learning to read* and *reading to learn* is clear cut. The dichotomy of *learning to math* and *mathing to learn* has long been stressed in math education, but that expression does not seem to roll off of one's tongue as easily. Similarly, for Information and Communication Technology (ICT).

Information and Communication Technology (ICT) now provides powerful aids to both learning and doing. The fact that many of these ICT aids are already being used by relatively young students suggests a strong need to restructure both the content and the order of the traditional curriculum.

In this section, I use the expressions *Learning to ICT* and *ICTing to Learn.* The general idea of learning to do something and then doing it in order to further increase one's knowledge and skills is inherent to all good teaching and is a fundamental aspect of education.

For a simple ICT example, consider a film camera and a digital camera. Film is relatively expensive and usually takes several days to get commercially developed. A digital photograph costs nothing (once one has a digital camera) and is available instantly. Even a preschool child can use a digital camera like the one built into a Smartphone or an inexpensive tablet computer. Think about learning to take digital photographs and taking digital photographs to learn about photography and in the study of many other subject areas.

In addition, there are a variety of computer-assisted instruction programs designed to help teach photography. These are learning by using computer simulations that provide an excellent environment for learning by doing and making use of feedback from one's own eyes (CameraSim, n.d.; Canon, n.d.).

For a more dramatic example, see Virtual Reality in the Science Lab (Moursund, 6/5/2016). This *IAE Blog* entry begins with a *learn by doing* quotation:

> "If you want to teach people a new way of thinking, don't bother trying to teach them. Instead give them a tool, the use of which will lead to new ways of thinking." (Richard Buckminster Fuller; American engineer, author, designer, inventor, and futurist; 1895-1983.)

The emerging Maker Culture and Maker Movement provide good examples of learning by doing. Computer technology empowers students of all ages to use their talents invent and make new things (Wikipedia, n.d.):

> The maker culture is a contemporary culture or subculture representing a technology-based extension of Do It Yourself (DIY) culture that intersects with hacker culture

(which is less concerned with physical objects as it focuses on software) and revels in the creation of new devices as well as tinkering with existing ones. The maker culture in general supports open-source hardware. **Typical interests enjoyed by the maker culture include engineering-oriented pursuits such as electronics, robotics, 3-D printing, and the use of Computer Numeric Control tools, as well as more traditional activities such as metalworking, woodworking, and, mainly, its predecessor, the traditional arts and crafts.** The subculture stresses a cut-and-paste approach to standardized hobbyist technologies, and it encourages cookbook re-use of designs published on websites and maker-oriented publications. **There is a strong focus on using and learning practical skills and applying them to reference designs.** [Bold added for emphasis.]

Final Remarks

All teachers face questions such as "Why do I have to learn this?" and "What's it good for?" I believe we educators can help answer such questions by developing curriculum that has an increased emphasis on doing–students making use of what they are learning. The **4th R** can be smoothly integrated into curriculum content, instructional processes, and assessment at all grade levels. This can be done in a manner that empowers students and also helps them to solve problems and accomplish tasks that they consider relevant.

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Chapter 6

A Personal Philosophy of Computers in Education

Based on I*AE Newsletter:* Issue 199, December 15, 2016.
See http://i-a-e.org/newsletters/IAE-Newsletter-2016-199.html

> "Mankind owes to the child the best it has to give." (United Nations Declaration of the Rights of the Child, 1959.)
>
> "Imagine a school with children that can read or write, but with teachers who cannot, and you have a metaphor of the Information Age in which we live." (Peter Cochrane; United Kingdom engineer, technologist, and entrepreneur; 1950-.)
>
> "If you want to teach people a new way of thinking, don't bother trying to teach them. Instead give them a tool, the use of which will lead to new ways of thinking." (Richard Buckminster Fuller; American engineer, author, designer, inventor, and futurist; 1895-1983.)

I believe that it is important for each educator develop a personal philosophy of education. It is important that this philosophy include the appropriate roles of computers in education, with an emphasis on Information and Communication Technology (ICT) and especially the roles of the **4th R** of **R**easoning/Computational thinking across all curriculum areas.

This chapter draws heavily from a talk I gave in 2006, and I have been working on the topic ever since (Moursund, February, 2006). My personal philosophy about education and computers in education continues to evolve continues to evolve (Moursund, 12/15/2016).

The Quotations at the Beginning of this Chapter

The three quotations given above provide some insight into my current philosophy of Computers in Education. Please re-read the quotations and think about some ideas that occur to you as you ponder each one. Doing so will help you to gain insight into your own current personal philosophy of education and computers in education.

Walt Disney's Magic Kingdom popularized the song *It's a Small World* written by Richard M. Sherman and Robert B. Sherman. Here is a small piece of the song:

It's a world of laughter
A world of tears
It's a world of hopes
And a world of fears
There's so much that we share
That it's time we're aware
It's a small world after all

Probably the tune is now going through your head. If not, you can listen to the tune at https://www.youtube.com/watch?v=rTuYTEG4fac. Want to learn more about Disneyland?

Short video clips are available at
https://www.youtube.com/channel/UCuRtXPHmnpkZetkb8ft7mzw.

I still find it amazing that a person can be reading an article from a computer screen, click on a piece of the article, and almost immediately be listening to a tune or viewing video clips that help the article to communicate more effectively. We certainly didn't have such things back in the days when I was a student. But, it is not at all amazing for the many children throughout the world now growing up in this online environment. It is the new norm–the world has indeed become "a small world". I strongly believe today's modern education must fully incorporate the steadily growing capabilities of ICT and the Web. I think of the Web as a library of the accumulated work of humankind. In the words of Albert Einstein:

> "A hundred times every day I remind myself that my inner and outer life are based on the labors of other men, living and dead, and that I must exert myself in order to give in the same measure as I have received and am still receiving." (Albert Einstein; German-born theoretical physicist and 1921 Nobel Prize winner; 1879-1955.)

Perhaps Einstein was exaggerating, but his statement raises an important idea. In our day-to-day activities, we depend on and build on the previous work of others. For example, a few minutes ago I turned on my computer. It draws electricity from a huge electrical generation and distribution system. The hardware and software of my computer represent the works of thousands of researchers, developers, and distributors. I think it is a good idea to thoroughly integrate this sense of our indebtedness to countless others into today's educational systems.

Developing a Personal Philosophy of Education and Computers in Education

Many years ago, some of my Computers in Education graduate students told me about a course they were taking, one in which they were required to develop a personal philosophy of education. They said it was one of the most useful assignments they had ever been asked to do. I remember sort of laughing at the time–who needs to write down a philosophy of education? Or, perhaps it was an embarrassed laugh. I had never given thought to my own philosophies of teaching math, computer science, and computers in education.

I have gradually matured over the years and now realize the value of that assignment. In thinking about my own philosophy of education, I am reminded of the Chinese proverb:

> "Give a man a fish and you feed him for a day. Teach a man to fish and you feed him for a lifetime."

As an educator, I gradually realized the educational importance of this proverb. As a computer educator, I gradually came to realize that it a major challenge to help people learn about possible roles of computers in education, and how to help them gain knowledge and skill relevant to their personal lives and careers.

Consider two very different philosophies of computers in education that I recently encountered while talking with two of my friends. The first said his philosophy of education is that teaching and learning are personal, human things. He believes that the heart of teaching and learning is the face-to-face interaction among students and teachers. In his opinion, distance education (online education via computer) has inherent weaknesses because a computer is not a human being.

The second friend said that computers are an extension to the human brain, a tool designed to supplement and extend the capabilities of a human brain. Much in the way that we integrate into our curriculum and daily lives the tools that aid our physical capabilities, we need to also integrate into our curriculum and daily lives the tools that aid our cognitive capabilities. We have certainly done that with reading and writing. We now need to do with the full range of ICT-based tools that are relevant to getting and making use of a good, modern, future-looking education.

I believe there is considerable merit in both of these philosophies. Neither rejects the study of knowledge and skills that we have deemed important in the past. What are your own thoughts, and how have they evolved over time? This is a key question. Presumably, many of your actions and deeds are based on your own personal philosophy. As the world changes, does your personal philosophy evolve? Are you flexible in your thoughts and deeds? Or you "stuck in a rut"?

Over the years, I have listened to many educators express their own philosophy of computers in education quite simply by saying, "Computers are here to stay." I cringe when I hear that statement, because it typically is followed by a quite shallow statement of the person's insights into the many possible and effective applications of computers in education.

For such people, I wonder about their philosophy of education in other areas of study. Have you ever heard a person say, "My philosophy of mathematics in education is that mathematics is here to stay"? How about other statements such as: "reading and writing are here to stay," "history is here to stay," or medicine is here to stay."

Surely, we can expect more than that from education professionals! I hope you agree with me that such superficial statements are not particularly useful in guiding a teacher in performing everyday tasks of curriculum development, teaching, and assessment. Nor are they very useful in interactions with students, parents, colleagues, and so on.

For many years I have argued that ICT has the potential to greatly improve our educational systems. Not only are computers here to stay, they will eventually revolutionize both the content and the processes of education. The remainder of this chapter is designed to help all educators (including parents, teachers, school administrators, and teachers of teachers) to understand that they need to develop a forward-looking philosophy of ICT in education that is designed to prepare today's students for their futures.

Keep in mind the fact that children tend to build their own philosophies from those of the adults they interact with. One characteristic of a good (human) teacher or parent is being a good (human) role model.

Your Beliefs

I am an old timer in the field of Computers in Education, having spent more than 50 years working in this discipline (Moursund, 2002; Moursund, 2018). Over these years, I have gradually developed a personal philosophy that helps to guide me in my teaching, writing, consulting, and presentations. I want to share some of my own ICT ideas and philosophy with you to think about as you examine/develop your own personal philosophy of computers in education.

You undoubtedly have your own education-related beliefs based on your upbringing, education, and life experiences. Here are some of mine:. I believe:

- A good education is an appropriate balance between developing "people-oriented" knowledge and skills, and learning to make effective use of the tools people have developed to augment and increase our physical and cognitive capabilities. We solve problems and accomplish tasks through using a combination of the capabilities of people and the capabilities of the tools that people have developed.
- The **4th R** of **R**easoning/Computational Thinking, including ICT and other technology-based change agents, can be used to make major improvements in the world's (and our country's) educational systems. I believe that the **4th R** will gradually become fully integrated into the first **3 Rs**, and will also continue as an important discipline in its own right, much like the many dozens of subject areas taught in our precollege and higher education systems.
- All of the world's children deserve the opportunity to gain a high-quality education that includes learning to make effective use of routine access to the communication facilities and knowledge base provided by the Internet and Web.
- Artificial Intelligence (including computerized robots and other tools) is a very powerful change agent. A modern education helps to prepare students for a life in which such computerized tools perform or help to perform more and more of the jobs that human workers are currently performing. They will also play an increasing role in our avocations and other aspects of our everyday lives.

I can easily expand my list of education-related beliefs. Over the years, in my professional career, I have developed habits of mind that incorporate these beliefs. I hope that you will make your own list of education-related beliefs, giving special attention to the **4th R** role of ICT in education. As you develop and come to understand the ramifications of your list, I hope that you will build your beliefs into a philosophy of computers in education that will effectively serve both yourself and the students you help to educate.

Final Remarks

A person's life is shaped by both nature (one's genes) and nurture (informal and formal education, and life experiences). For a newborn baby, most life experiences are new–they present opportunities to learn new things. Soon, however, an infant develops a knowledge and experience base, and this continues to grow throughout a lifetime. While a child's perceived world continues to change from day to day, gradually there is less "new" and more "same o', same o'".

As most adults age, there is a gradual decrease in the ability and/or desire and willingness to learn new information or skills to cope with change. Thus, for example, we see children mastering the learning of a second or third natural language, and learning to make relatively sophisticated use of new computer technologies, yet many adults struggle in such endeavors. However, until major cognitive decline sets in due to disease or other reasons, our brains continue to be able to learn.

A forward-looking educational system helps a student to learn and also to develop habits of mind that will support lifelong learning. These habits of mind need to include a personal philosophy of lifelong learning to meet one's changing personal needs in order to become and remain a responsible, contributing adult in our changing world.

Parents, guardians, and teachers serve as role models for children. I strongly encourage you to examine your personal philosophies of dealing with change as part of the role model you are setting for children and others.

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Part 2: Appendices

Preface to Part 2

> "We discovered that education is not something which the teacher does, but that it is a natural process which develops spontaneously in the human being. It is not acquired by listening to words, but in virtue of experiences in which the child acts on his environment. The teacher's task is not to talk, but to prepare and arrange a series of motives for cultural activity in a special environment made for the child." (Maria Montessori; Italian physician, educator, philosopher, humanitarian, and devout Catholic; 1870-1952.)

Since its inception, IAE has published well over 400 *IAE Blog* entries (*IAE Blog*, 2018). Part 2 reprints eight of these that I believe supplement and help to explain various ideas covered in chapters 1-6. I have made small corrections and additions to the original versions. Appendix 9 is a list of IAE publications that may be especially useful to teachers.

Appendix 1 provides an overview of problem solving and creative problem solving, background information that will be useful to many readers of this book.

Appendix 2 discusses reinventing our educational systems. Fully integrating the **4th R** of **R**easoning/Computational Thinking into our schools, from the PreK level through graduate school, would certainly constitute a reinvention!

Appendix 3 focuses on Quality of Life. For me, this is a very important topic. In the same sense that I consider a good education to be a birthright, I believe that a decent quality of life is also a birthright.

This is not to say that I believe each person will obtain the same (good) education and that each person will have the same (good) quality of live. However, I strongly believe that a good education tends to contribute to a person's quality of life. Thus, as we work to improve education, we need to think carefully about how the changes we propose will contribute to the quality of life of students, staff, parents, and others.

Appendix 4 explores virtual reality (VR). VR is already here. It is beginning to be a powerful force in entertainment, and it certainly has the capabilities of being a powerful aid to education.

Appendix 5 proposes the possibility that computers will eventually become more intelligent than humans. What will it do to the quality of life of humans if this actually happens? We know that some aspects of this have already occurred. For me, the GPS provides an excellent example. I have a very poor sense of direction and my GPS "gets me there" with much less difficulty than I can manage alone.

Appendix 6 presents the issues of Information Underload and Overload. ICT adds to our information overload, but also can help us to better deal with this overload. The **4th R** must address the issue of deciding what we want students to memorize and what we want them to be able to just "look up," understand, and effectively use in a timely fashion.

Appendix 7 discusses the idea that each teacher–indeed, all of us–might benefit by having a personal, computerized Digital Filing Cabinet designed and organized to fit our own individual information storage and retrieval needs.

Appendix 8 considers some of the changes that Information and Communication Technology (ICT) has brought to mathematics. It draws on an article by Keith Devlin, a leading math educator. Devlin presents the argument that ICT should be integrated into the math and other curriculum areas starting at the earliest levels of formal schooling. It also stresses the need for lifelong learning if one wants to "keep up" in any discipline of study.

Appendix 9 provides links to selected lists of free educational resources that may be especially useful to teachers.

References and Resources

IAE Blog (2018). *Information Age Education Blog* entries. Retrieved 7/19/2018 from http://i-a-e.org/iae-blog.html.

Appendix 1

Assessing and Teaching Creative Problem Solving

This appendix is a slightly modified version–with references updated–of the articles:

> Moursund, D. (9/6/2014). Assessing and Teaching Creative Problem Solving. *IAE Blog*. Retrieved 6/16/2018 from http://i-a-e.org/iae-blog/entry/creative-problem-solving.html.
>
> Moursund, D. (2018). Problem Solving. *IAE-pedia.* Retrieved 6/16/2018 from http://iae-pedia.org/Problem_Solving.

> "Each problem that I solved became a rule which served afterwards to solve other problems." (René Descartes; French philosopher, mathematician, scientist, and writer; 1596-1650.)

Throughout my professional career I have been interested in studying and teaching about problem solving. Most of the content of this appendix is from the *IAE Blog* in the first reference given above. However, this first section on Problem Solving comes from the *IAE-pedia* in the second reference. Some of the content of this appendix is also discussed in chapter 3.

Problem Solving

A Discipline of Study

Each academic discipline or area of study can be defined by a combination of general things such as:

- The types of problems, tasks, and activities it addresses.
- Its accumulated accomplishments such as results, achievements, products, performances, scope, power, uses, impact on the societies of the world, and so on.
- Its history, culture, and language, including notation and special vocabulary.
- Its methods of teaching, learning, assessment, and thinking. What it does to preserve and sustain its work and pass it on to future generations.
- Its tools, methodologies, and types of evidence and arguments used in solving problems, accomplishing tasks, and recording and sharing accumulated results.
- The knowledge and skills that separate and distinguish among: a) a novice; b) a person who has a personally useful level of competence; c) a reasonably competent person, employable in the discipline; d) an expert; and e) a world-class expert.

What Is a Problem?

Here is a definition of *problem* that fits well in many different disciplines. You (personally) have a problem if the following four conditions are satisfied:

1. You have a clearly defined given initial situation.

2. You have a clearly defined goal (a desired end situation). Some writers talk about having multiple goals in a problem. However, such a multiple-goal situation can be broken down into a number of single-goal problems.
3. You have a clearly defined set of resources that may be applicable in helping you move from the given initial situation to the desired goal situation. These typically include some of your time, knowledge, and skills. Resources might include money, the Web, the telecommunication system, computers, friends, teachers, and so on. There may be specified limitations on resources, such as rules, regulations, guidelines, and time lines for what you are allowed to do in attempting to solve a particular problem.
4. You have some ownership–you are committed to using some of your own resources, such as your knowledge, skills, time, and energy, to achieve the desired final goal.

I use the term *problem situation* to refer to a problem-like situation that is missing one or more of the four conditions listed above. This is an important point. A major goal in education is to help students learn to formulate well-defined (clearly defined) *problems* from the *problem situations* they encounter.

Problem solving includes:

- Question situations: recognizing, posing, clarifying, and answering questions.
- Problem situations: recognizing, posing, clarifying, and then solving problems.
- Task situations: recognizing, posing, clarifying, and accomplishing tasks.
- Decision situations: recognizing, posing, clarifying, and making good decisions.
- Using higher-order critical, creative, wise, and foresightful thinking to do all of the above. Often the results are shared, demonstrated, or used as a product, performance, or presentation.

In many problem-solving situations, Information and Communication Technology (ICT) and computerized tools are resources of the type mentioned in #3 of the four-part definition of a problem. These resources have grown more powerful over the years. That is one reason why the **4th R** of **R**easoning/Computational Thinking is so important. It is why I so strongly believe we must thoroughly integrate teaching about and integrating the use of the **4th R** across the curriculum.

Item #4 in the definition of a problem is particularly important. Unless you have ownership–through an appropriate combination of intrinsic and extrinsic motivation–you do not have a problem. Motivation, especially intrinsic motivation, is a huge topic in its own right.

For example, you glance at the headlines in your local newspaper and see that a drought in a particular country in Africa is causing widespread hunger. Hundreds of thousands of people are on the verge of starvation.

This hunger and starvation situation satisfies the first three components of the definition of a problem. Moreover, the story touches your heart. But what–if anything–can or will you do about it? It is one thing for a problem situation to touch your heart. It is another situation entirely for you to decide to commit some of your resources such as time, money, contacts with other people, political power, and so on to do something about helping to solve the problem.

Now, think about the types of *problems* that we assign students as seatwork and/or homework. Many students look at these assigned tasks and mentally respond, "I couldn't care less. These are just make-work busy work–a hoop that I am supposed to jump through." That is, these students have no ownership of the problems.

A good teacher creates learning situations in which students are willingly engaged in working on assigned (and/or student created) problems and tasks. We want students to learn to look beyond their immediate gratification toward possible futures in which the knowledge and skills gained will be long-term rewards.

Creative Problem Solving

(Note: This section is quoted from the *IAE Blog* entry dated 9/6/2014 listed at the beginning of this appendix.)

Informal and formal education–along with personal drive and a number of other factors–enter into how well people develop and use their natural curiosity and creativity (Moursund, 12/24/2010). Each of us can help our self and the people with whom we interact to become better at creative problem solving. Quoting from the Wikipedia (2018):

> **Creativity** is a phenomenon whereby something new and valuable is created (such as an idea, a joke, an artistic or literary work, a painting or musical composition, a solution, an invention etc.).

This is a very broad definition. When I think a thought and express it orally or in writing, this is an act of creativity. The thought doesn't have to be new to others or to the whole world. Similarly, when I am faced by a problem that is a challenge to me and I manage to solve the problem, I consider this to be an act of *creative problem solving*.

Thus, we are all creative problem solvers. Through informal and formal education and practice, we become better at it.

The 2014 PISA Assessment

The 2014 Program for International Student Assessment (PISA) was designed to measure 15-year-olds in math, science, and reading. In addition, it was designed to measure *creative problem solving.*

Quoting Holly Yettich from the article U.S. Students Score Above Average on First PISA Problem-Solving Exam (4/1/2014):

> U.S. 15-year-olds scored above average on a first-of-its-kind international assessment that measured creative problem-solving skills.
>
> …
>
> The assessment, which was the subject of an Organization for Economic Cooperation and Development (OECD) report released Tuesday, **defined creative problem-solving as the ability to "understand and resolve problem situations where a method of solution is not immediately obvious."**

> …
>
> U.S. performance was especially strong on tasks designed to measure interactive problem solving, which requires students to find some of the information they need on their own. [Bold added for emphasis.]

After reading Yettich's article, I did a search of my own IAE-published writings for the term *creativity*. I was somewhat surprised to see that I have used that term in 27 of my *IAE Blog* entries. In addition, I have recently added a section on creativity to my Brain Science entry in the *IAE-pedia* (Moursund, 2018a).

There is considerable literature on teaching creative problem solving. My 9/3/2014 Google search of the expression *teaching creative problem solving* produced nearly 4 million results. My 6/16/2018 search of the same expression produced 61,400,000 results.

At every level of education, teachers integrate creative problem solving into the courses they teach. Many schools teach separate courses on creative problem solving (coursea, 2018).

Teaching Creative Problem Solving

Each discipline of study focuses on solving problems and accomplishing tasks within a limited area. The problems and tasks in the fine and performing arts are different from the problems and tasks in the sciences or in the humanities/social sciences.

A student studying in a particular discipline is faced by the challenge of the huge and steadily growing accumulation of knowledge and skills in that discipline. One approach to studying a discipline is to study some of the problems that it has already solved. This approach includes developing some "basic skills" within the discipline. The study of discipline-specific basic skills types of problems can provide students with a beginning level of understanding of how the discipline deals with some of its most important problems and tasks.

Another approach is to learn for understanding and to practice on challenging problems that stretch one's current knowledge and skills within a discipline. The goal is to move beyond basic skills–to learn to deal with novel, challenging problems within the discipline.

A curriculum driven by high-stakes testing tends to take the former approach, and a curriculum designed to teach understanding and creative problem solving tends to take the latter approach. Both of these approaches are important, and students have varying levels of strengths, weaknesses, and personal preferences in these two general approaches to learning.

Each discipline of study has its own approaches to teaching creative problem solving. Thus, for example, suppose that you are interested in teaching math. Both physical and virtual math manipulatives are a powerful aid to teaching and learning math. Within this environment it is possible for teachers to pose problems that challenge a wide range of students and that encourage creative problem solving (Kelly, July, 2006; Lepi, September, 2014).

The steadily increasing capabilities of computer-based information retrieval systems tends to decrease the advantages of becoming very good at rote memorization and to increase the value of creatively attacking and solving novel problems.

Higher-order and Lower-order Skills

Benjamin Bloom chaired a committee that developed the taxonomy that bears his name and also edited the first volume of the 1956 text, *Taxonomy of Educational Objectives: The Classification of Educational Goals* (Bloom, 1956). In the initial publication, the cognitive domain was divided into Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. The first three levels are considered to be "lower order" and the second three are considered to be "higher order." While the definitions have been somewhat modified over time, the basic ideas have held up well (Clark, n.d.).

Benjamin Bloom and his colleagues were bothered by the fact that much of the college teaching at their time focused on lower-order skills. Nowadays, there is a strong trend toward placing increasing emphasis on higher-order skills at both the precollege level and in higher education.

I am particularly interested in approaches to teaching and learning for creative problem solving that are useful in many different disciplines. The next four sub-sections provide examples I have frequently used in my own teaching.

Assess Your Students' Insights

Think about a group of students that have varying levels of expertise (varying levels of knowledge and skill) in an area in which you will be teaching them a sequence of lessons (Moursund, 2018b). What problems, tasks, and questions will the students learn to successfully deal with through the unit of study? You are particularly interested in improving their creative problem-solving knowledge and skills. In what follows, I use the term "problem solving" to include solving problems, accomplishing tasks, and answering questions.

A good starting point is to assess their current level of knowledge and skills. Ask your students to spend a few minutes writing down examples of two types of problems, tasks, and questions about this area of study:

1. Problems (problems, tasks, questions) that they think they can solve, but ones they consider to be "hard." For example, you can encourage them to pose problems that they can solve but that they believe some/many of their classmates cannot solve.
2. Problems (problems, tasks, questions) that they would like to be able to solve by the end of the unit of study.

Have students share some of their examples in small groups. While they are doing this, wander around the classroom and listen to their ideas. Then have a whole class discussion in which you draw on students' ideas and integrate these into your goals for the unit of study.

Posing Researchable (Possibly Answerable) Questions

In my university-level teaching, I wanted my students to understand and make use of the concept of a researchable (possibly answerable) question. Here are two general, somewhat overlapping, categories of such higher-order questions:

1. A question that is possibly answerable by research and analysis based on the current accumulated and reasonably accessible knowledge of the human race.

2. A question that is possibly answerable through the design and implementation of a research study designed to add new knowledge to the accumulated human knowledge. Typically, such research begins with a literature search making use of the Web and other readily available resources.

This type of question posing activity can be carried out with students at any school level. As students progress in school, they can become better at posing and learning how to answer higher-order questions.

Wait Time

When you are about to ask your class a question, first think about how much time you will wait before you take an answer. This is called *wait time.* The types of questions that lead to an immediate popping up of hands are almost always lower-order.

Substantial research on *wait time* has been available for many years. Quoting from Mary Budd Rowe (1986):

> This paper describes major outcomes of a line of research begun nearly 20 years ago by the author on a variable called **wait time**. To put it briefly, when teachers ask questions of students, they typically wait 1 second or less for the students to start a reply; after the student stops speaking they [teachers] begin their reaction or proffer the next question in less than 1 second. If teachers can increase the average length of the pauses at both points, namely, after a question (wait time 1) and, even more important, after a student response (wait time 2) to 3 seconds or more, there are pronounced changes (usually regarded as improvements) in student use of language and logic as well as in student and teacher attitudes and expectations.

In my own teaching of teachers, I frequently ask a question and then orally analyze the extent to which it is higher-order before I accept an answer. This wait time and analysis helps my students gain insights into what I call higher-order questions, and it gives them time to think about an answer.

Group Brainstorming

Brainstorming in groups is an activity designed to encourage higher-order, *divergent* thinking. Quoting from the Wikipedia:

> **Brainstorming** is a group or individual creativity technique by which efforts are made to find a conclusion for a specific problem by gathering a list of ideas spontaneously contributed by its member(s). The term was popularized by Alex Faickney Osborn in the 1953 book *Applied Imagination.* Osborn claimed that brainstorming was more effective than individuals working alone in generating ideas, although more recent research has questioned this conclusion. See: http://en.wikipedia.org/wiki/Brainstorming - cite_note-DiehlStroebe61-1.

Here is information supporting the last sentence quoted above. Quoting from an article in *The New Yorker* titled Groupthink (Lehrer, 1/30/2012):

> The underlying assumption of brainstorming is that if people are scared of saying the wrong thing, they'll end up saying nothing at all. The appeal of this idea is obvious: it's always nice to be saturated in positive feedback. Typically, participants leave a brainstorming session proud of their contribution. The whiteboard has been filled

> with free associations. Brainstorming seems like an ideal technique, a feel-good way to boost productivity. **But there is a problem with brainstorming. It doesn't work.** [Bold added for emphasis.]
>
> …
>
> Brainstorming didn't unleash the potential of the group, but rather made each individual less creative. Although the findings did nothing to hurt brainstorming's popularity, numerous follow-up studies have come to the same conclusion. Keith Sawyer, a psychologist at Washington University, has summarized the science: "Decades of research have consistently shown that brainstorming groups think of far fewer ideas than the same number of people who work alone and later pool their ideas."

What You Can Do

Develop a personal definition of creative problem solving that fits well into your professional and personal life. As you go through a day, stop occasionally to reflect on the types of problems you are dealing with at that time, and the creativity you are using to deal with these problems. What do you do in an "ordinary" day to improve your own creative problem-solving skills? Then think about what you are doing to help others–such as your students and colleagues–to reflect on and improve their creative problem-solving skills.

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Appendix 2

Reinventing Our Educational Systems

This appendix is a slightly modified version–with references updated–of the article:

> Moursund, D. (8/26/2016). Reinventing Our Educational System. *IAE Blog.* Retrieved 7/12/2018 from http://i-a-e.org/iae-blog/entry/reinventing-our-educational-system.html.

> "Nothing could be more absurd than an experiment in which computers are placed in a classroom where nothing else is changed." (Seymour Papert; South African/American mathematician, computer scientist, and educator; 1928-2016.)

Many of the people working to improve our educational systems appear to be looking backward. They fix on measures of success that were deemed worthy in the past, and they strive to have our schools perform still better in meeting these same measures. Many of the goals of education in the past are still worthy goals. However, some are out of date and some need to be changed. For example, "look it up in a dictionary" has long been an important idea. Today, we now have online dictionaries that can pronounce words. Moreover, the online dictionaries define more words than one finds in an inexpensive hardcopy dictionary and are more frequently updated. To me this suggests that we should now assess a student's skills in using an online dictionary.

For another example, consider an encyclopedia. In the past, there might be one set of encyclopedias in a classroom, and some homes had a set. Now, every student can have access to the encyclopedia-like Wikipedia that is much more comprehensive than the hard-copy encyclopedias. Moreover, every child can have access to the far larger database of information that we call the Web.

Here is an interesting question to ask yourself: "Do we want children to learn to use, and then to use routinely, voice input to online dictionaries and encyclopedias, and voice output from these information sources?" As you can see, proposed changes in education raise difficult questions!

Now think about spelling. Through dint of years of study and a good memory, some children can become very good at spelling and can compete successfully in spelling contests. Others who spend less time in learning to spell and/or who are less gifted at this task learn to make do with a smaller vocabulary that they can comfortably use in their writing. Are spelling tests good measures of how well our education system is doing? Is memorizing lists of spelling words a good way to spend one's school time? I am not very good at spelling. The advent of online dictionaries and spell checkers built into word processors have greatly enriched my life and improved my writing skills.

A much larger concern, however, is that the world is changing, and many of the past measures of success are becoming less important for today's children. Tony Wagner is one of my favorite authors on the topic of needed changes in education. Quoting from a 2010 *IAE Newsletter* (Moursund & Sylwester, 6/15/2010):

> Tony Wagner (2008) is a professor in the Harvard Graduate School of Education and co-director of the Change Leadership Group. In his work, he distinguishes between students gaining competencies (knowledge) in various disciplines and students developing habits of mind.
>
> …
>
> Throughout his book, Wagner stresses seven Survival Skills that he feels need to be major drivers in a modern education.
>
> A1. Critical thinking and problem solving.
>
> A2. Collaboration across networks and leading by influence.
>
> A3. Agility and adaptability.
>
> A4. Initiative and entrepreneurism.
>
> A5. Effective oral and written communication.
>
> A6. Accessing and analyzing information.
>
> A7. Curiosity and imagination.

Notice that none of these is discipline specific. Wagner argues that each discipline-specific course should be a vehicle for helping students to develop these **interdisciplinary habits of mind.**

In his *TED Talk*, What the World Cares About Is Not What You Know, But What You Can Do with What You Know, Wagner discusses the seven A1 to A7 Survival Skills. He argues that knowledge is now a commodity, emphasizing that a person can become better at each of these through study and practice (Wagner, April, 2012).

A more recent Mindshift article, When Educators Make Space for Play and Passion, Students Develop Purpose, contains a few minor modifications to Wagner's list (Mindshift, 8/25/2015). The B1 to B7 Mindshift list that follows corresponds to Wagner's A1 to A7 list of Survival Skills. I have added my current insights to each as a **Moursund comment.** These comments summarize what I believe it takes to be successful lifetime learners.

B1. Formulate good questions.

Moursund comment: Problem posing is a key aspect of problem solving. Notice the shift in emphasis from having students answer questions posed by teachers and others, to having students pose question of personal interest–questions in which they have some ownership. Ownership is a key idea in problem solving. See appendix 1 of the book you are currently reading, and my *IAE-pedia* article on Problem Solving (Moursund, 2015).

Quoting from the Wikipedia (2018b):

> **Problem-posing education** is a term coined by Brazilian educator Paulo Freire in his 1970 book *Pedagogy of the Oppressed*. Problem-posing refers to a method of teaching that emphasizes critical thinking for the purpose of liberation. Freire used problem-posing as an alternative to the banking model of education.

B2. Communicate in groups and lead by influence.

Moursund comment: This is a variation on 2A in Wagner's list. Solving problems and accomplishing tasks often involves collaboration of a group and leaders who can influence others to work together toward a common goal. Nowadays, this routinely involves electronic communications and use of (collaborating with) computers. The idea of collaborating with an artificially intelligent machine adds a new dimension to problem solving.

B3. Be mentally agile and adaptable.

Moursund comment: Among other things, this requires being open to change and to learning to make effective use of the growing human knowledge and the tools for using this knowledge. Students need to learn the capabilities and limitations of their brains working alone, working in groups, and working with the aid of computers. See my book on *Brain Science for Educators and Parents* (Moursund, August, 2015).

B4. Take initiative and be entrepreneurial.

Moursund comment: Each of us has capabilities that we can learn to use to improve our own lives and the lives of others. Using a very broad definition of being entrepreneurial, these are entrepreneurial activities. I personally like to think about the idea of using one's own initiative and entrepreneurship to help improve quality of life for one's self and others.

B5. Have effective written and oral communication skills.

Moursund comment: The Internet and Web provide us with new tools for oral, written, and graphical communication. Our educational system is being slow to appreciate and make use of how readily children adapt to and enjoy using these new tools.

B6. Know how to access and analyze information.

Moursund comment: See the sequence of *IAE Newsletters* on Credibility and Validity of Information (Moursund & Sylwester, 2014-2015). An important aspect of analyzing information is determining its veracity. Just because something is in hardcopy print or published electronically does not make it true. Indeed, "fake news" and other deliberately false information is now routinely published and is readily available to our students (Farmer, 5/31/2018).

B7. Be creative and imaginative.

Moursund comment: Young children have a great deal of creative ability and wild imaginations. Our current educational system is weak in fostering and building on this innate creativity and imagination. See chapter 6 of my book, *Brain Science for Educators and Parents* (Moursund, August, 2015). Also see appendix 1 of the book you are currently reading.

What You Can Do

You undoubtedly have heard about the idea of a military-industrial complex. Quoting from the Wikipedia article Military-Industrial Complex (Wikipedia, 2018a):

> The term is most often used in reference to the system behind the military of the United States, where it gained popularity after its use in the farewell address of President Dwight D. Eisenhower on January 17, 1961.

We now have a very large and powerful *commercial-political educational complex* that is becoming increasingly commercialized and is highly resistant to the type of changes proposed by Tony Wagner. However, a large and important component of education is informal (determined by parents and students) and another large and important component is still determined by individual teachers. Parents, teachers, and individual students can be guided by Wagner's ideas. Think carefully about what you are currently doing and what you can continue to do in this very important endeavor!

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Appendix 3

Improving Worldwide Quality of Life

This appendix is a somewhat updated version of the article:

> Moursund, D. (2/12/2016). Improving Worldwide Quality of Life. *IAE Blog*. Retrieved 6/30/2018 from http://i-a-e.org/iae-blog/entry/improving-worldwide-quality-of-life.html.

> "Never doubt that a small group of thoughtful committed citizens can change the world; indeed, it's the only thing that ever has." (Margaret Mead; American cultural anthropologist; 1901–1978.)

I have discussed *Quality of Life* (QoL) in two previous *IAE Blog* entries (Moursund, 2/5/2016; Moursund, 12/24/2014). Also see my *IAE Newsletter*, Education and Quality of Life (Moursund, 3/31/2018).

While we each have our own ideas on how to measure and improve our own quality of life, considerable progress has occurred in developing global measures and goals. The *Social Progress Index* has developed a standard to rank societies based on how they meet the needs of citizens. Quoting from the *Social Progress Index* website (2018):

> MEASURING NATIONAL PROGRESS – To truly advance social progress, we must learn to measure it, comprehensively and rigorously. The Social Progress Index offers a rich framework for measuring the multiple dimensions of social progress, benchmarking success, and catalyzing greater human wellbeing. The 2015 version of the Social Progress Index has improved upon the 2014 version through generous feedback from many observers and covers an expanded number of countries with 52 indicators.

Michael Green is part of the team that created the *Social Progress Index.* In his *TED Talk,* How We Can Make the World a Better Place by 2030, he explores world Global Goals (Green, October, 2015):

> Do you think the world is going to be a better place next year? In the next decade? Can we end hunger, achieve gender equality, halt climate change, all in the next 15 years?
>
> Well, according to the governments of the world, yes we can. In the last few days, the leaders of the world, meeting at the UN in New York, agreed on a new set of Global Goals for the development of the world to 2030.… [These] goals are the product of a massive consultation exercise. The Global Goals are who we, humanity, want to be.

United Nations Global Goals

Quoting from UN 2030 Agenda (2015):

> This Agenda is a plan of action for people, planet and prosperity. It also seeks to strengthen universal peace in larger freedom. We recognize that eradicating poverty

> in all its forms and dimensions, including extreme poverty, is the greatest global challenge and an indispensable requirement for sustainable development.
>
> All countries and all stakeholders, acting in collaborative partnership, will implement this plan. We are resolved to free the human race from the tyranny of poverty and want and to heal and secure our planet. We are determined to take the bold and transformative steps that are urgently needed to shift the world on to a sustainable and resilient path. As we embark on this collective journey, we pledge that no one will be left behind.

How to Achieve the UN Global Goals

The first part of Michael Green's 2015 *TED Talk* cited above discusses a previous set of UN goals. Quoting again from his talk:

> Back in 2001, the UN agreed to another set of goals, the Millennium Development Goals. And the flagship target there was to halve the proportion of people living in poverty by 2015. The target was to take from a baseline of 1990, when 36 percent of the world's population lived in poverty, to get to 18 percent poverty this year.
>
> Did we hit this target? Well, no, we didn't. We exceeded it. This year, global poverty is going to fall to 12 percent. Now, that's still not good enough, and the world does still have plenty of problems. **But the pessimists and doomsayers who say that the world can't get better are simply wrong.** [Bold added for emphasis.]

This is huge progress. But with the current (December, 2016) world population in excess of 7.3 billion, the 12% figure represents well over 800 million children living in poverty.

Each country has its own definition of what constitutes living in poverty. In the United States, the National Center for Children in Poverty estimates that in 2016, about 20% of American children were living in poverty (NCCP, 2016). Clearly, the definition being used in the United States is not the same as the definition being used by the United Nations as it measures worldwide poverty levels.

At the Millennium Summit in September, 2000, the largest gathering of world leaders in history adopted the UN Millennium Declaration, committing their nations to a new global partnership to reduce extreme poverty and setting out a series of time-bound targets, with a deadline of 2015, that have become known as the Millennium Development Goals. Quoting from this declaration (UN, n.d.):

> The Millennium Development Goals (MDGs) are the world's time-bound and quantified targets for addressing extreme poverty in its many dimensions-income poverty, hunger, disease, lack of adequate shelter, and exclusion-while promoting gender equality, education, and environmental sustainability. They are also basic human rights-the rights of each person on the planet to health, education, shelter, and security.

The remainder of Michael Green's *TED Talk* analyzes the steps needed to meet the year 2030 goals. He begins by discussing poverty. It remains a major worldwide problem, but further progress in reducing poverty is only a small part of what needs to be done to achieve the 2030 goals. Quoting again from his talk:

> We have countries that are underperforming on social progress, relative to their wealth. Russia has lots of natural resource wealth, but lots of social problems. China has boomed economically, but hasn't made much headway on human rights or environmental issues. India has a space program and millions of people without toilets. Now, on the other hand, we have countries that are over performing on social progress relative to their GDP. Costa Rica has prioritized education, health and environmental sustainability, and as a result, it's achieving a very high level of social progress despite only having a rather modest GDP. And Costa Rica's not alone. From poor countries like Rwanda to richer countries like New Zealand, we see that it's possible to get lots of social progress, even if your GDP is not so great.

Final Remarks

Despite the bad news that pervades our daily news media, the world is making good social progress in working for a better Quality of Life (QoL). Michael Green emphasizes the value of having well-defined goals and measures of how well the world is doing at the global and national levels to achieve these goals. Quoting the Cheshire Cat from Lewis Carroll's *Alice in Wonderland*:

> "If you don't know where you are going, any road will get you there."

More generally, this statement holds for the entire field of problem solving. Often the most challenging aspect of attempting to deal with a specific problem situation is extracting from it a clearly defined (and understandable) goal.

What You Can Do

Here is an activity that can be used with a classroom group of students, a grade-level group, a school, and so on. Develop a long-range set of goals for improving the quality of life of a group of people. For example, at the secondary school level the task might focus on goals for a school, neighborhood, or community. The project requires developing and agreeing on a set of goals for a good quality of life, developing measurable goals, doing research on past progress in achieving the goals, and carefully analyzing/planning how to achieve the goals.

A similar activity can be individualized for each student. Ask each student to individually think about and perhaps write about, "Where are you headed in the future? What steps can you be taking now and in the near future to help you reach your longer-term goals?" Many websites discuss this student activity. For example, see How to Help Students Set and Reach Their Goals (Romano, et al., n.d.).

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Appendix 4

Virtual Reality Science Lab

This appendix is a slightly modified version–with references updated–of the article:

> Moursund, D. (6/5/2016). Virtual Reality Science Lab. *IAE Blog.* Retrieved 6/17/2018 from http://i-a-e.org/iae-blog/entry/virtual-reality-in-the-science-lab.html.

> "The medium is the message." (Herbert Marshall McLuhan; Canadian philosopher of communication theory and a public intellectual; 1911-1980.)
>
> "If you want to teach people a new way of thinking, don't bother trying to teach them. Instead give them a tool, the use of which will lead to new ways of thinking." (Richard Buckminster Fuller; American engineer, author, designer, inventor, and futurist; 1895-1983.)
>
> "Nothing could be more absurd than an experiment in which computers are placed in a classroom where nothing else is changed." (Seymour Papert; South African/American mathematician, computer scientist, and educator; 1928-2016.)

I am very interested in what is "coming down the pike" of technology innovations that may greatly improve our educational system. I recently viewed a *TEDx Talk*, This Virtual Lab Will Revolutionize Science Class, that literally blew my mind (Bodekaer, October, 2015).

My short *IAE Blog* entry cannot begin to capture the current and emerging capabilities of relatively inexpensive virtual reality to make major improvements in the quality and effectiveness of science education. However, here are a few of the highlights of Bodekaer's short video. I assume that you will take the time to view the video.

First, the virtual lab incorporates a Smartphone for each user. Since the annual worldwide production of Smartphones is now about 1.5 billion (one per every five people on earth) the availability of this part of the hardware is no longer a major issue (Business Wire, 2018). Remember, today's Smartphone has as much compute power as the multimillion dollar super computers from 25 to 30 years ago.

Second, the Smartphone is inserted into a relatively inexpensive headset that easily slips on and off one's head. In the presentation, some of the audience members were provided with the equipment and seemed to quickly adjust to it.

Third, the virtual lab provides users with access to a very modern science lab with many millions of dollars of equipment. For example, there is a gene sequencer, an electron microscope, and the ability to miniaturize oneself and move around the inside of an object at the level of individual molecules. Again, remember, these are all "virtual" (computer-simulated) lab devices.

Fourth, the virtual lab includes built-in computer-assisted instruction and access to online instructional and research articles.

Fifth, the virtual lab has a “built-in” virtual teacher, but a human teacher can supplement and/or fill this role. That is, a student functioning in this virtual reality laboratory can be interacting with a human (live) teacher who is functioning in the same lab.

While functioning in this virtual laboratory, a student can learn to use the “real” equipment needed to carry out experiments traditionally done with the actual equipment in a physical lab–but not have to deal with the dangers and expenses of using such equipment in the physical lab. Such “real” equipment is highly computerized, and the user interface for this equipment also is highly computerized.

This aspect of learning to do science laboratory work is not much different from the now routine use of computer simulations by researchers and developers in their everyday work. In essence, the virtual experiments and the computer simulation-based real experiments are in many cases nearly identical. Thus, it is possible for today’s students to do cutting edge research via use of a virtual lab and computer simulations.

Research and Development in Materials Science

The previous section mentioned computer simulations as now being a routine tool of researchers in the sciences. A *Scientific American* article by Gerbrand Ceder and Kristin Persson describes how the computer has changed the entire field of materials science (Ceder & Persson, 11/19/2013). Quoting from the article:

> In 1878 Thomas Edison set out to reinvent electric lighting. To develop small bulbs suitable for indoor use, he had to find a long-lasting, low-heat, low-power lighting element. Guided largely by intuition, **he set about testing thousands of carbonaceous material**s–boxwood, coconut shell, hairs cut from his laboratory assistant's beard. After 14 months, he patented a bulb using a filament made of carbonized cotton thread.” [Bold added for emphasis.]

Engineered materials such as chip-grade silicon and fiber-optic glass underpin the modern world. Yet, as illustrated by Thomas Edison’s work, designing new materials has historically involved a frustrating and inefficient amount of guesswork.

Streamlined versions of the equations of quantum mechanics–along with supercomputers that, using those equations–can virtually test thousands of materials at a time. This is eliminating much of that guesswork involved in developing new materials. In essence, computerized simulations using the mathematics of quantum mechanics produces a huge increase in the speed of certain types of trial and error in the materials sciences.

Researchers are now using this method, called high-throughput computational materials design, to develop new batteries, solar cells, fuel cells, computer chips, and other technologies.

In Summary

Quoting again from Bodekaer’s *TEDx* presentation:

> We basically set out to create a fully simulated, one-to-one, virtual reality laboratory simulator, where the students could perform experiments with mathematical

> equations that would simulate what would happen in a real-world lab. But not just simple simulations–we would also create advanced simulations with top universities like MIT, to bring our cutting-edge cancer research to these students. And suddenly, the universities could save millions of dollars by letting the students perform virtual experiments before they go into the real laboratory. And not only that; now, they could also understand–even on a molecular level inside the machine–what is happening to the machines. And then they could suddenly perform dangerous experiments in the labs as well.
>
> But we didn't stop there, because we had seen just how important meaning is for the students' engagement in the class. So we brought in game designers to create fun and engaging stories. For instance, here in this case, where the students have to solve a mysterious CSI murder case using their core science skills.

The developers of this virtual reality system engaged a team of researchers to study 160 college students from Stanford University and Technical University of Denmark. This study provided what I would call "promising" evidence of greatly increased student learning. Moreover, when the virtual reality students had a real human teacher to interact with in the virtual laboratory, learning results were further improved.

Final Remarks

In the preceding paragraph I used the term "promising" because a single research study is inadequate in providing "solid" evidence of the effectiveness of a complex innovation. A number of companies are working on virtual reality systems and beginning to sell their products to the general public. In that sense, this provides strong evidence that virtual reality has now arrived. It is proving to be a marketable entertainment product.

Bodekaer's *TEDx Talk* provides an example of how virtual reality can be used in education, both in higher education and at the precollege level. A computerized version of the tools that students need to learn to use can become the teacher. This idea is discussed in chapter 4 of my book, *Technology and Problem Solving: PreK-12 Education for Adult Life, Careers, and Further Education* (Moursund, 9/13/2015).

The following statement summarizes my view of the future of teaching machines: **The tool is the teacher.** That is, a computerized tool that a student wants to learn how to use will increasingly contain built-in computer-assisted instructional materials that teach the student. I believe this is a paradigm shift that is beginning to occur in education. It will take years of curriculum development, teacher education, and work on convincing our educational systems that this is a good way to go. However, there is much that you can do now.

What You Can Do

As a teacher and/or parent, think carefully about the essence of what is illustrated in the virtual lab educational system described above. It represents a huge change from our current immersion of students in a "traditional" oral, pencil-and-paper, and print materials approach to learning and using one's learning. This traditional and still widely used educational approach is steadily becoming more and more outdated as science laboratory instruments change. For a summary of key ideas in authentic instruction and assessment, see Mueller's Authentic Assessment Toolbox (Mueller, n.d.).

Over recent decades, however, our traditional educational systems have steadily become less authentic. Your current students are facing an adult life in a world that is substantially different than it was when you were a child. What you can do is to routinely provide examples of this difference as you interact with your students and/or your children. Draw on both their knowledge and your own knowledge of tools such as digital cameras, handheld calculators, Smartphones, video games (these provide good examples of computer simulations), computerized toys (these provide examples of robots and computerized machinery), Web and search engines, Internet, GPS, voice input/output to a variety of devices, and so on.

You and your students/children already use these new technologies effectively in everyday life outside of school. **It's time to bring these tools into the classroom!**

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Appendix 5

Education for the Coming Technological Singularity

This appendix is a slightly modified version–with references updated–of the article:

> Moursund, D. (3/3/2015). Education for the Coming Technological Singularity. *IAE Blog*. Retrieved 11/30/2016 from http://i-a-e.org/iae-blog/entry/education-for-the-coming-technological-singularity.html.

> "In times of change, the learner will inherit the earth while the learned are beautifully equipped for a world that no longer exists." (Eric Hoffer; American social writer and philosopher; 1902-1983.)

> "It is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change." (Charles Darwin; English scientist and naturalist; 1809-1882.)

> "Intelligence is the ability to adapt to change." (Stephen W. Hawking; British theoretical physicist and cosmologist; 1942-.)

> "The secret of change is to focus all of your energy, not on fighting the old, but on building the new." (Socrates; Greek philosopher; circa 469 BC-399 BC.)

This is the second of a two-part *IAE Blog* entry about our rapidly changing technology. The previous blog entry introduced the idea of a *technological singularity* (Moursund, 2/25/2015). The term technological singularity refers to sometime in the future when computers become much "smarter" than people.

Right now, the rate of technological change is both large and increasing. However, we have had considerable change in the past. We often attempt to forecast some of the changes that we think are coming, but such forecasts are often incorrect. I chuckle each time I read Thomas Edison's 1913 forecast:

> "Books will soon be obsolete in the schools.... Scholars will soon be able to instruct through the eye. It is possible to touch every branch of human knowledge with the motion picture." (Thomas A. Edison; American inventor and businessman; 1847-1931.)

We now have artificially intelligent computer systems that are more capable than humans in certain limited areas, and we have artificially intelligent robots that are taking over many jobs previously performed by human workers. However, we still seem far away from a time in which computer intelligence and capabilities exceed human intelligence and capabilities over the broad range of human endeavors.

Remember, the current estimated life expectancy of today's precollege students is about 80 years. So, our current K-12 educational system is preparing students for what they will do during the 60 or more years after they leave high school. Think back over the changes our world has seen in the past 60 years. Now try to imagine what would constitute a good education for a future of 60 years of rapidly accelerating change.

The next two sections provide my current insights and recommendations about this question.

Educational Implications: Foundational Ideas

This *IAE Blog* entry is motivated by the (possibly coming) technological singularity, and our current high and accelerating pace of technological change. Our educational system is currently facing many other challenges, and they are not going away!

First, consider the current balance between a *past-oriented* and a *future-oriented* education. When the world was changing only slowly, a past-oriented education served us well. Adults could easily adjust to the very small number of Science, Technology, Engineering, and Mathematics (STEM) changes that occurred during their lifetime.

This slowly evolving educational system served humanity well even as reading, writing, and arithmetic were developed and very, very slowly were introduced to the masses. Most of the world's population remained illiterate for thousands of years after the development of these three "basics" of today's education.

Reading, writing, and arithmetic, along with oral communication skills, remain essential today. However, the technology-enhanced environment in which we perform these activities has changed. A modern and future-looking educational system prepares students to function well in our current "connected and computerized" world, and also lays a foundation that will help our future adults adjust to continuing rapid technological progress.

Second, consider aids to teaching and learning. Books were (and still are) a tremendous aid, as were audio and video recording and playback systems. All of these, and much more are available in today's state-of-the-art teaching machines. Such teaching machines are interactive and make effective use of modern technological aids to learning and doing reading, writing, arithmetic–and also **thinking, problem solving, and communication.** *Technology and Problem Solving: PreK-12 Education for Adult Life, Careers, and Further Education* is a free short book that provides an overview of such teaching machines (Moursund, 2015).

Third, consider the idea of learning to work with computer technology rather than compete with it. What can human beings do well that computers cannot do or can only do quite poorly? We need to help all of our students better understand the intrinsic human characteristics that make us so different from computers.

We are a very long way from having computers that have the knowledge and skills of a caring, loving, human with well-developed and routinely used good "people skills." An increasing number of future jobs will go to job seekers who have well-developed "human" strengths and who can employ these strengths when working with robots and general-purpose computer systems.

Educational Implications: Specific Recommendations

This section contains my current specific recommendations to students, parents, and others who are concerned about today's students getting a modern education.

To begin, think about **what distinguishes people from the machines and tools humans have developed** as aids to their physical and mental capabilities. Perhaps words such as compassion, empathy, loyalty, tenderness, and spirituality come to mind. Perhaps you think about sharing feelings such as love, joy, happiness, sadness, fear, and anger. Some people have love-hate relationships with their car or computer, but these are not reciprocated from the tools back to the people.

Here are some specific recommendations:

- Develop your "people" and communication skills. Become fluent in face-to-face, written, and computer-aided communication skills. If you have the opportunities to do so, become bilingual and bicultural. Become a *people person* and a *citizen of the world.*
- Focus your education on gaining higher-order, creative thinking, understanding, and problem-solving knowledge and skills in whatever areas you decide to study. Select some areas that interest you and that fit with your innate capabilities, and work to build a significant level of expertise in these areas.
- Learn about current and near-term capabilities and limitations of computers and robots. Plan your education and develop your abilities so that you do not end up in head-to-head competition with computers and robots in areas that the robots are already quite good at and are steadily becoming better (Moursund, 2/11/2015; Boehm, 2/8/2014).
- Make very sure that you learn to make effective and fluent use of Information and Communication Technology (ICT), both in general use and in the discipline areas you choose to study. Remember, the combination of a human brain and a computer brain can often outperform either one working alone (Moursund, 2014).
- If you are "really into" computers, continue to develop your computer knowledge and skills, but also work toward gaining a high level of expertise in one or more other career. This will help prepare you for many of the new jobs that are being developed that require a combination of ICT and "traditional" knowledge and skills.
- Develop learning skills and habits of mind that will serve you throughout your lifetime. For example, learn about persistence along with the concepts of intrinsic motivation, reflection, and instant gratification. (Moursund, 1/28/2014.)
- Identify your specific physical and mental strengths and weaknesses as a learner and "doer" in each area that you study. Develop and exploit your strengths, and work to overcome your weaknesses.
- This final recommendation is specifically for students. Think about what you want in your future. What informal and formal education do you need to help ensure that you will achieve a decent quality of life? Remember the quote, "All work and no play makes Jack a dull boy." Make sure that you gain knowledge and skills that support possible avocations, hobbies, and other non-vocational aspects of your future. (See also appendix 3 for additional information.)

How Fast Is Technology Changing?

The following chronological list captures billions of years of "intellectual" change. I find it helps me to think about the very slow pace of change for billions of years, and the increasingly rapid current and likely future pace of change.

1. Life on earth started with in the first simple cells and their genetic coding of information using RNA and later DNA. This began about 3.6. billion years ago. Within a hundred million years, multi-celled life forms developed. A DNA molecule stores the equivalent of about 1,000 books of data.
2. Over the next three billion years, more complex life forms developed. Life forms developed with a precursor to a brain of gradually increasing complexity to store and process information. By a half-billion years ago a basic ganglia structure existed in some animals, and this is considered to be a start of a brain. It provided information storage that supplemented the DNA storage, and eventually evolved into our current mammalian brain.
3. The first primate-like animals developed about 65 million years ago. They were a product of well over three billion years of evolution. It was a mere 200,000 years ago that anatomically modern humans with our current brains developed. The storage capacity of a human brain is probably in the range of two million to two billion books. (The size of this range is an indication that we still don't know much about the details of how neurons store information.) Our brains both store and process information. We both learn and forget.
4. A mere 5,300 years ago, writing and reading were developed by humans as aids to storing and retrieving information. We finally had long-term information storage that could easily be shared among many people and relatively accurately passed on from generation to generation. Libraries could grow in size and additional libraries could be built.

Less than 80 years ago, electronic digital computers were developed as aids to storing, processing, and retrieving information. Now, a single "run" of the Large Hadron Collider produces about 30 petabytes of data–the equivalent of about 30 billion books. Today's fasted supercomputers can perform 200,000 trillion calculations per second, or 200 petaflops (Morris, 6/9/2018). Personally, that number is so large that I can't really comprehend it. This is more than 25 million calculations a second for every person on earth. Perhaps it is helpful to think of this computer doing more calculations in one second than all of the people on earth could do in their lifetimes using traditional pencil and paper methods.

Photography, telephones, television, electronic storage and playback devices, and computers are all predecessors to today's Smartphone. The first commercially available telephone combining the concepts of intelligence, data processing, and visual display screens into telephones became available in 1993. Both in 2013 and in 2014, total worldwide production of Smartphones was about 1 billion per year–that is, about one for every seven people on earth in each of these two years. By 2018, this had grown to about 1.5 billion Smartphones a year, or about one for every five people on earth.

The *smartness* of Smartphones is quite impressive and increasing year to year. Some of the *smartness* features are: a Global Positioning System; a voice input and output system;

and access to increasingly smart Web search engines. Some of the artificially intelligent smartness is built into a Smartphone, and some comes from access to and use of the steadily growing accumulation of human knowledge stored on the Web and in other digital libraries. That is, the Smartphones that people are buying right now continue to increase in capability and intelligence through progress in improving the smartness of devices outside of computers and improving the capabilities of the global communications network.

Final Remarks

Here are two quotes that capture the essence of this *IAE Blog* entry:

> "We must welcome the future, remembering that soon it will be the past; and we must respect the past, remembering that it was once all that was humanly possible." (George Santayana; Spanish citizen raised and educated in the United States, generally considered an American man of letters; 1863-1952.)

> "In times of change, the learner will inherit the earth while the learned are beautifully equipped for a world that no longer exists." (Eric Hoffer; American social writer and philosopher; 1902-1983.)

What You Can Do

> "When you teach, you learn twice." (Seneca; Roman philosopher and advocate of cooperative learning; 4 BC-65 AD.)

Your knowledge, skill set, and insights make you different from every other person. As you interact with other people, you are both a teacher and a learner. As a teacher, you can help shape the future lives of many people.

Select a couple of the bulleted items in the Specific Recommendations section that seem particularly important to you. Bring these ideas up in discussions with your colleagues and students. Especially, share them with your students and engage them in thinking about how the ideas are being integrated into their current education. Listen carefully to–and learn from–their insights into what they believe would improve the education they are receiving.

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Appendix 6

Information Underload and Overload

This appendix is a slightly modified version–with references updated–of the article:

> Moursund, D. (3/1/2016). Information Underload and Overload. *IAE Blog*. Retrieved 6/17/2018 from http://iae-pedia.org/Information_Underload_and_Overload.

> "Knowledge is of two kinds. We know a subject ourselves, or we know where we can find information upon it." (Samuel Johnson; British author and father of the English dictionary; 1709-1784.)

> "Before you become too entranced with gorgeous gadgets and mesmerizing video displays, let me remind you that information is not knowledge, knowledge is not wisdom, and wisdom is not foresight. Each grows out of the other, and we need them all." (Arthur C. Clarke; British science fiction author, inventor, and futurist; 1917-2008.)

This *IAE Blog* entry is about my recently revised and updated version of the *IAE-pedia* entry, Information Underload and Overload (Moursund, 2016). This has proven to be a popular article, with about 75,000 hits to date. Since I first wrote this document in 2009, the total amount of information available on the Web and from other sources has grown remarkably.

Reading, writing, and arithmetic (math) became formal subjects in schools more than 5,000 years ago. Since then there has been a steady increase in the accumulated knowledge of the human race. The pace of this increase has been increasing. Quoting from the article, Knowledge Doubling Every 12 Months, Soon to be Every 12 Hours (Schilling, 4/19/2013):

> Buckminster Fuller created the "Knowledge Doubling Curve"; he noticed that until 1900 human knowledge doubled approximately every century. By the end of World War II knowledge was doubling every 25 years. Today things are not as simple as different types of knowledge have different rates of growth. For example, nanotechnology knowledge is doubling every two years and clinical knowledge every 18 months. But on average human knowledge is doubling every 13 months. **According to IBM, the build out of the "internet of things" will lead to the doubling of knowledge every 12 hours.** [Bold added for emphasis.]

Learn more about information explosion in the Wikipedia article (2018). This is not a new concern. Quoting from the Wikipedia article:

> In 1910 during the town planning conference of London Daniel Burnham noted that "But it is not merely in the number of facts or sorts of knowledge that progress lies: it is still more in the geometric ratio of sophistication, in the geometric widening of the sphere of knowledge, which every year is taking in a larger percentage of people as time goes on." and later on "It is the argument with which I began, that a mighty change having come about in fifty years, and our pace of development having

> immensely accelerated, our sons and grandsons are going to demand and get results that would stagger us."

Information Overload, Underload, and Appropriate Load

It is easy to see why so many people experience *information overload*–too much information. I certainly see it when I do a Web search and get a hundred thousand or more results!

Information underload refers to the situation where we don't have ready access to information needed to help us solve problems and accomplish tasks that we face. Of course, the information may not exist. That is why we have so many researchers working to provide authentic new information. Much more frequently, for most of use, we don't have the information immediately available in our heads and/or we don't know how to find it quickly from the Web and other information sources.

Consider an Information scale with one end labeled *Overload* and the other end labeled *Underload.* Let's label the middle of the scale *Appropriate Load.* This reminds me of the Goldilocks story in which the bowls of porridge were too hot, too cold, and just right; the beds were too hard, too soft, and just right.

For a particular person faced with a particular information need, there might be too much information available, too little information available, or an appropriate (for the person) amount of information available. Moreover, the information might be written at a level that is way over the person's head, way under the person's reading and understanding levels, or appropriate to the person.

Educators are familiar with this situation. A dictionary with a quite limited number of words, and containing illustrative pictures and simple definitions, is appropriate to a student just learning to read. Books for students at different grade levels have readability levels appropriate to average students at those grade levels.

Now, think about this situation from the point of view of the creators of the Wikipedia. They envisioned a collection of articles (information) that would eventually exceed that in any current print encyclopedia and that articles would be authored by many different writers. What readability level should it have? What background knowledge of the subject of a particular article should the writer of the article assume the readers will have?

Every writer faces the challenge faced by authors of Wikipedia entries. Every educational system and every teacher face the challenge of meeting the information needs of a very wide range of students with different interests, background knowledge, and reading/viewing skills.

Retrieving Just the Information One Needs

Part of the information underload problem is that often one cannot find the needed information, even in cases where it exists. The various Web search companies and many other groups are working on this problem. What is emerging is a three-pronged approach:

1. Increase the breadth and depth of information available of the Web. Develop more intelligent search engines that order the search results in a manner that better fits the needs of people using the Web. Currently Google is the most widely used of such search engines.

2. Make use of user-specific search, answer, and teaching engines. (To a large extent, this is still the future of search engines.) Such a system would "know" a great deal about what the question poser knows and would provide information and answers that are individualized to that person. Moreover, such a system views a question as a "teachable moment" and uses it to provide not only the desired information but also appropriate instruction to help the question poser learn more about the topic area. However, note the dangers of having still more computer systems that "know" a great deal about specific users. This critical problem has come to the forefront as more and more large databases have been compromised by hackers.

3. Develop answer engines that are designed specifically to produce answers to problems (including questions) posed by users. Two important examples of this are:

   - **WolframAlpha.** See https://www.wolframalpha.com/. This is a computational knowledge engine. This is an online service that answers factual questions. It comes in a limited free version and a (not free) professional version. Among other things, the system "knows" a lot of math and can solve a wide range of such problems.
   - **IBM's Watson.** See http://www.ibm.com/watson/. Watson gained fame by defeating two past champions in the TV question and answer program Jeopardy in 2011. IBM is now developing such artificially intelligent question answering systems for use in medicine and a number of other areas.

Final Remarks

A good, modern education acknowledges and makes use of the information available to today's students. It prepares students to make use of and build on this accumulated knowledge of the human race. Moreover, it assumes that it is preparing students for adult life in a world in which computer-based aids to learning and using information are readily available in daily life, on the job, and in further lifelong education.

What You Can Do

As I have mentioned many times in my writing and presentations, I consider each person to be both a lifelong learner and a lifelong teacher. The rapidly changing face of information storage, retrieval, and use provides an excellent opportunity for each of us to be a learner and a teacher. I hope that you will do so and thoroughly enjoy these activities.

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Appendix 7

Personal Digital Filing Cabinet for Every Teacher

This appendix is a slightly modified version–with references updated–of the article:

> Moursund, D. (10/1/2013). A Personal Digital Filing Cabinet for Every Teacher. *IAE Blog.* Retrieved 6/18/2018 from http://i-a-e.org/iae-blog/entry/a-personal-digital-filing-cabinet-for-every-teacher.html.

> "Try to learn something about everything and everything about something." (Thomas H. Huxley; English writer; 1825-1895.)

The *IAE-pedia* has been updated and expanded over the past several months. I believe that the updated entry on *Digital Filing Cabinets* is now one of the more important entries in the *IAE-pedia* (Moursund, 2016a).

The idea is very simple. We now have quite good technology that makes it easy for each preservice and inservice teacher to accumulate a personal library of "good stuff." I call such a collection a *Personal Digital Filing Cabinet (PDFC).*

All teachers accumulate materials that they find useful in their teaching. It is now convenient to have quite a bit of such material available in electronic digital form so it can be easily accessed, edited, copied, and shared. Here are two key ideas of such a personal library:

1. As you develop this library and make extensive use of it, you gain personal ownership of and familiarity with the content. In some sense it becomes an extension of your brain. Browsing through your collection can help you to retrieve a memory that you have temporarily forgotten.
2. You can readily share your personal library with professional colleagues, students, parents of your students, and others. This facilitates the development of a lifelong habit of listening to education-related needs of others and providing them with content that you are comfortable in sharing and that you feel is relevant to their needs.

The *IAE-pedia* began as my own project to develop a rather comprehensive Personal Digital Filing Cabinet (PDFC) for myself. All of the initial files, and many added since then, are a combination of personal memory dumps and extensive browsing of the Web for materials that I find useful and want to share with others. The resulting *IAE-pedia* has evolved into a sort of public PDFC. My collations of quotations provide good examples of *IAE-pedia* entries that I have developed over a long period of years (Moursund, 2018a; 2018b). In total, these two collections of quotations have had more than 140 thousand page views.

Notice that such a "personal" digital library is quite different from the concept of the very extensive electronic "impersonal" libraries such as the Web. Your PDFC contains materials that you have personally studied and used. It is information that you consider to be "tried and true." Moreover, it can gain in value over time. Each time you access a document, you can add a comment that explains what you were looking for and whether the article was helpful. You can add thoughts on possible other uses of the document, and other places in your Personal Digital Filing Cabinet that you have found useful when searching on the topic you currently have in mind.

A Bit of History

I first started thinking and writing about the idea of preservice and inservice teachers having a personal digital library of teaching/learning materials years before the World Wide Web (developed by Tim Berners-Lee in 1990-1991) became available. At that time, I was particularly interested in math education and I envisioned that a student entering a teacher education program could be provided with a free CD-ROM containing a reasonably extensive library of math content and math education materials.

Of course, in those days most preservice and inservice teachers had a personal print library of books, "handouts," course notes, and so on that they had accumulated and were building. But I envisioned giving every preservice and inservice teacher a CD with a relatively large electronic library of books, lesson plans, assessment instruments, state math standards, and similar documents. These would be specifically related to the math content, instructional processes, and assessment they were studying and using. I strongly believed that this would help to improve math education.

Nowadays, most of the materials I envisioned are available free on the Web. But they are sort of buried in the billions of Web documents preservice and inservice math teachers can access.

Suggestions to Teacher Education Programs

One of the things I would like to see happen is for each teacher education institution or program of study to develop a Digital Filing Cabinet that is aligned to its courses, programs of study, and other college/university coursework relevant to preservice and inservice teachers. For example, it may be that preservice elementary teachers take a Math Methods course from the College of Education and one or more Math for Elementary Teachers courses from the Mathematics Department. Each of these types of courses needs to be covered in a Digital Filing Cabinet made available to students in the teacher education program (Moursund, 2016b).

On a larger scale, I would like to see the teacher education programs in each state collaborate in developing a Digital Filing Cabinet for the state. Preservice and inservice teachers in a state have a lot in common, and they can benefit from having a State Digital Filing Cabinet that reflects the various programs of study and the curriculum standards of the state.

Personal DFCs for Each K-12 Student

Here is an idea that I believe many teachers and their students will find useful. Each student can be building a Personal DFC, and adding material to it year-after-year from what they are studying and learning in their formal schooling and informal education.

While such a collection is not a portfolio, it can certainly have some portfolio-like characteristics. It is becoming common for grade school students to begin to develop portfolios of their schoolwork and other activities. The process includes selecting representative samples of one's work and writing a critical analysis of the work. This is an important aspect of learning to self-assess and learning to take responsibility for one's education.

A student's Personal DFC provides a historical record of what the student has been taught in school and has studied/learned both inside and outside of school. It can contain information about the books studied and personal likes and dislikes at the time. Besides its personal historical record, it can provide help in reviewing and relearning what one has learned in the past.

In such a project, considerable care must be given to protecting the privacy of each individual student. Remember, this is to be a **personal** DFC and may well have some of the characteristics of a personal diary.

What You Can Do

Analyze the progress you are making (or, the lack of progress) in having a Personal Digital Filing Cabinet relevant to your own professional career. If you feel your current progress is inadequate to your lifelong learning and professional needs, decide to do something about this–and, then do it!

Explore the extent to which the PDFC ideas from this article have been implemented in your professional circles. If progress is occurring, contribute to it. If the idea of a PDFC seems to be totally inadequate or missing in your preservice, inservice, and professional circles, take the initiative and start such a project.

References and Resources

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Appendix 8

Thoughts About a Modern Mathematics Education

This appendix is a slightly modified version–with references updated–of the article:

> Moursund, D. (2/1/2017). Keith Devlin's Thoughts About a Modern Mathematics Education. *IAE Blog*. Retrieved 7/12/2018 from http://i-a-e.org/iae-blog/entry/keith-devlin-s-thoughts-about-amodern-mathematics-education.html.

> "Mathematics is the gate and key of the sciences... Neglect of mathematics works injury to all knowledge, since one who is ignorant of it cannot know the other sciences or the things of this world." (Roger Bacon; English philosopher and naturalist; 1214-1294.)

Keith Devlin has long been a world class math educator. This *IAE Blog* entry discusses his recent article, All the Mathematical Methods I Learned in My University Math Degree Became Obsolete in My Lifetime (Devlin, 1/1/2017). Quoting Devlin:

> When I graduated with a bachelor's degree in mathematics from one of the most prestigious university mathematics programs in the world (Kings College London) in 1968, I had acquired a set of skills that guaranteed full employment, wherever I chose to go, for the then-foreseeable future–a state of affairs that had been in existence ever since modern mathematics began some three thousand years earlier. **By the turn of the new Millennium, however, just over thirty years later, those skills were essentially worthless, having been very effectively outsourced to machines that did it faster and more reliably, and were made widely available with the onset of first desktop- and then cloud-computing.** In a single lifetime, I experienced first-hand a dramatic change in the nature of mathematics and how it played a role in society. [Bold added for emphasis.]

Now, in 2017, we can look back and ask what progress undergraduate math education has made in light of the observation by Devlin and many others. During this time, computer hardware, software, and connectivity have continued to make rapid progress. This progress has greatly changed how colleges graduates solve the problems and accomplish the tasks in the disciplines they have studied. Of course, the amount of change varies considerably from discipline to discipline.

Just for the fun of it, I examined the current requirements in the undergraduate math program of study at Kings College London. From the material I found on the Web, it is clear that this is a very challenging and rigorous program of study. But, I saw no mention of computers in the program description, nor any requirements in the field of Computer and Information Science. Clearly, the faculty in this program believes that rigorous math is good math, and rigorous math is what a good bachelor's degree in math is all about.

The bachelor's degree in mathematics at my alma mater, the University of Oregon, requires far less courses in mathematics than does the Kings College London, but requires more breadth of study outside of mathematics. In addition, it offers a joint Math/Computer Science degree (University of Oregon, 2018). Quoting from this document:

> Are you fascinated by the challenges and excitement of computer and information science? Do you also have a consuming interest in mathematics? With this major, you can explore the realm of computer and information science while developing a mathematics anchor. If you want to gain knowledge in both fields, but don't initially want to specialize in either, this may be the major for you.
>
> The knowledge you gain in this major is hugely practical in the real world. Computer science offers the challenge and excitement of a dynamically evolving science, the discoveries and applications of which affect every aspect of modern life. **You will choose classes from areas such as programming languages, modeling and simulation, human-computer interaction, and artificial intelligence.** [Bold added for emphasis.]

The Fourth R: Reasoning/Computational Thinking

Reading, writing, and arithmetic (math)–the **3 Rs**–are considered to be the basics of education. At the PreK-12 level, students are required to take year after year of coursework in these areas. If students go on to college, they typically are required to take additional coursework in one or more of these areas. Indeed, a great many students entering college do so poorly on placement exams that they are required to start their college work with remedial courses that do not carry credit toward their degree (ACT, 2015). Quoting from the ACT article:

> The ACT (2015) provides data annually on the percentages of students going on to college who were "qualified" in English, Reading, Mathematics, Science, and All Four Subjects. The site referenced above provides data for the past five years. During that time, the percentage qualified in all four areas went from 25% to 28%. English, Reading, and Math showed modest declines, and science showed a modest increase. In summary, the situation has not improved much over the past five years, and over 70% of students entering college need to take remedial coursework in one or more of the basic subject areas.

This suggests to me that there is a mismatch between what high schools are expecting of college-bound students, and what colleges and universities are expecting. This is not a recent problem. The very first *IAE Blog* entry I wrote discussed this issue (Moursund, 8/22/2010). In that blog entry I noted:

> New data show that fewer than 25% of 2010 graduates who took the ACT college-entrance exam possessed the academic skills necessary to pass entry-level courses, despite modest gains in college-readiness among U.S high-school students in the last few years.

We live at a time when a **4th R** of **R**easoning/Computational Thinking has emerged. This **4th R** makes use of both human brain and computer brain to answer questions, represent and solve problems, and accomplish tasks.

In earlier chapters of the book you are currently reading, I strongly recommend that the **4th R** be thoroughly integrated throughout the PreK-12 curriculum in each discipline area that students study during their many years in school. In higher education, I recommend that the **4 Rs** be treated equally, and thoroughly integrated into each course students take. The emphasis on each of the **4 Rs** should, of course, be appropriate to the specific discipline a course is covering.

My major thesis is that it takes years and years of study and use to develop an appropriate modern level of competence in each of the **4 Rs**. Currently there are two major movements approaching this in computer education. The first is to teach some computer programming to all precollege students, and the second is to require some computer science coursework at the college level.

Both of these approaches have merit, and each has strong supporters. However, both are weak in that they do not focus on integrating Information and Communication Technology (ICT) knowledge and skills into the new knowledge and skills the students are gaining as they progress through their PreK-12 and further education. This integration requires that all teachers have the computer knowledge and skills appropriate to the level and disciplines they teach, and that all curriculum content reflect this "modern" use of ICT.

Kelsey Sheehy's article, Computer Science Transitions from Elective to Requirement, presents some of the ICT progress being made in higher education (Sheehy, 4/3/2012). She quotes Geoffrey Bowker, professor of informatics at the University of California-Irvine:

> "Yes, [computer science] absolutely should be [required]," says Geoffrey Bowker, professor of informatics at the University of California–Irvine. All aspects of our personal lives and our work lives are affected by computers. We need to know about the tools that we're working with."
>
> …
>
> "Getting a flavor of science is great," he says. "**But computer science is not a flavor; it's a staple.**" [Bold added for emphasis.]

Bowker's point is consistent with my own point of view that ICT is both a discipline of study and a tool useful across the curriculum. It is a "staple" in a modern education.

What You Can Do

No matter what your current level of informal and formal education, you are living at a time of very rapid pace of change in your world. This is likely to affect your own future and the future of many people you care about. Think carefully about what you are going to do to help yourself and others to deal with these changes. Perhaps start with an analysis of what you are currently doing. If you are not fully satisfied with your analysis, start to become more proactive. Set some learning and teaching goals for yourself. Then, **"Make it so."**

References and Resources

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Appendix 9

Lists of Free Educational Resources

The Fourth R (Second Edition) includes a large number of links to resources that support the various topics being presented and discussed. Appendix 7 focusses on building your own *Personal Digital Filing Cabinet* (PDFC). A PDFC can be thought of as an extension of the idea of having your own personal collection of books and other print materials.

As one example, the online *IAE-pedia* was originally conceived of as being my own PDFC where I write and collect information that I want to save and to share with others. Perhaps the most important idea in this task has been that of developing a personal ownership of the PDFC content. Each document that I write for and publish on the IAE websites represents a considerable investment of my cognitive and time resources. I write about topics that I find personally interesting, and take satisfaction in being able to share them freely with a wide audience of educators and other readers.

Appendix 9 is a compilation of online educational resources from a wide variety of sources. The first section is a brief introduction to *Fair Use,* an important concept to understand when using any online materials. See Openly Licensed Educational Resources (Moursund, 10/22/2015). The second section lists many of the online resources written and published by IAE that are available free on the IAE websites. The third section has lists compiled by IAE of free online resources available from a wide variety of other sources.

All of the lists are free for readers to copy and distribute, and reference to IAE as the source of the list is always appreciated. I also will appreciate additions to any of the lists that readers will bring to my attention at moursund@uoregon.edu.

Introduction to Fair Use

The totality of collected data, information, knowledge, and wisdom is growing very rapidly. The Web and other computerized information storage and retrieval systems have opened up much of this collection to students and teachers. Such materials are an important resource for teaching, learning, and problem solving. I particularly appreciate the following quote:

> "Knowledge is of two kinds. We know a subject ourselves, or we know where we can find information upon it." (Samuel Johnson; British author and father of the English dictionary; 1709-1784.)

There are many documents that list relatively simple guidelines about fair use of copyright materials. **They typically come with a warning that these guidelines are not guaranteed to protect a user from being sued.** However, such guidelines are quite useful and can help to reduce the stress on teachers and students who want to make educational use of copyrighted materials.

The Internet has raised new issues of intellectual property rights. Many teachers and students are confused about their legal rights to make teaching and learning uses of these materials. Quoting from a 2007 *eSchool News* article originally available at https://www.eschoolnews.com/news/showstoryts.cfm?Articleid=7430 but no longer available on the Web:

> Teachers face conflicting information about their rights, and their students' rights, to use copyrighted works, the report says. They also face complex and often overly constrictive copyright policies in their own institutions. As a result, they use less effective teaching techniques, teach and transmit false copyright information, and do not take advantage of new digital platforms for their instruction.
>
> "This is not only unfortunate but unnecessary, since copyright law permits a wide range of uses of copyrighted material without permission or payment," the report says. "**Educational exemptions sit within a far broader landscape of 'fair use.'** However, educators today have no shared understanding of what constitutes fair-use practices."
>
> In layman's terms, fair use is "a statutory exemption to the rights of copyright owners," says Kenneth Crews, a legal scholar at the Indiana University School of Law in Indianapolis. **There are four key factors that help decide whether use of copyrighted material constitutes fair use, he said: (1) the purpose of your use, (2) the nature of the work, (3) the amount you're using, and (4) the effect of your use on the market.** [Bold added for emphasis.]

Fair use is a complex legal issue. Moreover, we live in a litigious time. Thus, many people are fearful of the possibility of being sued by copyright holders. Fair use is, of course, related to intellectual property law. Quoting from Design Decisions Wiki (n.d.):

> In law, intellectual property (IP) is an umbrella term for various legal entitlements which attach to certain names, written and recorded media, and inventions. The holders of these legal entitlements may exercise various exclusive rights in relation to the subject matter of the IP. The term intellectual property reflects the idea that this subject matter is the product of the mind or the intellect. The term implies that intellectual works are analogous to physical property and is consequently a matter of some controversy.
>
> Intellectual property laws and enforcement vary widely from jurisdiction to jurisdiction. There are inter-governmental efforts to harmonize them through international treaties such as the 1994 World Trade Organization (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs), while other treaties may facilitate registration in more than one jurisdiction at a time. Disagreements over medical and software patents and the severity of copyright enforcement have so far prevented consensus on a cohesive international system.

The Stanford University Libraries provides an extensive website on Copyright and Fair Use. Quoting from the chapter on Fair Use (Stanford University Libraries, n.d.):

> Fair use is a copyright principle based on the belief that the public is entitled to freely use portions of copyrighted materials for purposes of commentary and criticism. For example, if you wish to criticize a novelist, you should have the freedom to quote a portion of the novelist’s work without asking permission. Absent this freedom, copyright owners could stifle any negative comments about their work.

> Unfortunately, if the copyright owner disagrees with your fair use interpretation, the dispute may have to be resolved by a lawsuit or arbitration. If it's not a fair use, then you are infringing upon the rights of the copyright owner and may be liable for damages.
>
> The only guidance for fair use is provided by a set of factors outlined in copyright law. These factors are weighed in each case to determine whether a use qualifies as a fair use. For example, one important factor is whether your use will deprive the copyright owner of income. Unfortunately, weighing the fair use factors is often quite subjective. For this reason, the fair use road map can be tricky to navigate.
>
> This chapter explains the various rules behind fair use principles. To help you get a feel for which uses courts consider to be fair uses and which ones they don't, several examples of fair use lawsuits are provided at the end of this chapter.

How does the court know if a use is fair? Quoting from Teaching Copyright, a project of the Electronic Frontier Foundation (Teaching Copyright, n.d.):

> Whether a use is fair will depend on the specific facts of the use. Note that attribution has little to do with fair use; unlike plagiarism, copyright infringement (or non-infringement) doesn't depend on whether you give credit to the source from which you copied. Fair use is decided by courts on a case-by-case basis after balancing the four factors listed in section 107 of the Copyright Act. Those factors are:
>
> - The purpose and character of the use of copyrighted work.
> - Transformative quality - Is the new work the same as the copyrighted work, or have you transformed the original work, using it in a new and different way?
> - Commercial or noncommercial - Will you make money from the new work, or is it intended for nonprofit, educational, or personal purposes? Commercial uses can still be fair uses, but courts are more likely to find fair use where the use is for noncommercial purposes.
> - The nature of the copyrighted work.
> - A particular use is more likely to be considered fair when the copied work is factual rather than creative.
> - The amount and substantiality of the portion used in relation to the copyrighted work as a whole.
> - How much of the copyrighted work did you use in the new work? Copying nearly all of the original work, or copying its "heart," may weigh against fair use. But "how much is too much" depends on the purpose of the second use. Parodies, for example, may need to make extensive use of an original work to get the point across.
> - The effect of the use upon the potential market for or value of the copyrighted work.

- This factor applies even if the original is given away for free. If you use the copied work in a way that substitutes for the original in the market, that will weigh against fair use.
- Uses of copyrighted material that serve a different audience or purpose are more likely to be considered fair.
- The effect of the use upon the potential market for or value of the copyrighted work. This factor applies even if the original is given away for free. If you use the copied work in a way that substitutes for the original in the market, that will weigh against fair use. Uses of copyrighted material that serve a different audience or purpose are more likely to be considered fair.

These factors are guidelines, and they are not exclusive. As a general matter, courts are often interested in whether or not the individual making use of a work has acted in good faith.

Plagiarism

Plagiarism is the practice of taking work done by others and passing it off as one's own work. Quoting from What is Plagiarism (**P**.org, 5/18/2017):

According to the Merriam-Webster online dictionary, to "plagiarize" means:

- to steal and pass off (the ideas or words of another) as one's own
- to use (another's production) without crediting the source
- to commit literary theft
- to present as new and original an idea or product derived from an existing source

In other words, plagiarism is an act of fraud. It involves both stealing someone else's work and lying about it afterward.

While there is a fine line between fair use and plagiarism, in most cases a student's plagiarism is blatant and obvious to a teacher. Teachers have the responsibility of helping their students to learn the difference between fair use and plagiarism.

Free Online Resources Published by IAE

A large number of different authors have contributed articles to the IAE publications. If you are interested in writing for IAE, please read the *IAE Newsletter*, Writing to Help Improve Education: An Invitation to Write for IAE, available at http://i-a-e.org/newsletters/IAE-Newsletter-2018-235.html.

IAE-pedia

The *IAE-pedia* currently contains 289 documents. These are revised and updated from time to time. Over the years, a number of new documents have been added, and some documents have been deleted. In total, the *IAE-pedia* has had about ten million page-views since it began a little more than ten years ago. Visit the *IAE-pedia* at http://iae-pedia.org/Main_Page.

IAE Newsletter

The *IAE Newsletter* has been published twice a month since its beginning about ten years ago. The term *newsletter* is somewhat misleading. Each issue provides an in-depth treatment of a single topic. In some cases, a sequence of newsletters is used to present a series of viewpoints on the one topic. Indeed, IAE has published seven "newsletter-based" books, each containing a collection of newsletters on an important issue in education. All back issues of the *IAE Newsletter* are available at http://i-a-e.org/iae-newsletter.html.

IAE Blog

The *IAE Blog* has no fixed publication schedule, and each blog entry is a rather short article on a single topic. Over a period of time, several blog entries may address the same topic. For example, I am particularly interested in Quality of Life, and how a good education contributes to having a good quality of life. As of 7/1/2018, there have been more than three million page-views of the 420 back issues of the *IAE Blog* currently available at http://i-a-e.org/iae-blog.html. A chronologically-ordered list containing each title with its Web address is available at http://iae-pedia.org/IAE_Blog.

Free IAE Math Education Materials

See http://iae-pedia.org/Free_IAE_Math_Education_Materials. Since the beginning of my professional career, I have been interested in math education and the possible uses of computers to help improve math education. A number of the most popular *IAE* publications are about math education. These Free IAE Math Education Materials document provides brief discussions about and links to a large number of *IAE* books, *IAE-pedia* pages, *IAE Blog* entries, and *IAE Newsletters* that focus on math education. One unifying theme is the improvements in math education being made possible by the use of Information and Communication Technology.

Here is a list of the math articles that are in the top 30 (in terms of page-views) of the *IAE-pedia* documents as of 7/16/2018.

- Improving Math Education (270,641 views)
- Good Math Lesson Plans (242,042 views)
- Communicating in the Language of Mathematics (181,613 views)
- Math Maturity (147,382 views)
- Math Word Problems Divorced from Reality (97,854 views)
- Digital Filing Cabinet: Math Education (96,771 views)
- Math Education Quotations (94,426 views)
- Free Math Education Videos (91,941 views)
- Word Problems in Math (83,246 views)
- Math Project-based Learning (82,507 views)
- Math Methods for Preservice Elementary Teachers (81,952 views)

Free Online IAE Books

- Free books by Dave Moursund. *IAE-pedia.* Retrieved 6/18/2018 from http://iae-pedia.org/David_Moursund_Books.
- Free books by Bob Albrecht. *IAE-pedia.* Retrieved 6/18/2018 from http://iae-pedia.org/Robert_Albrecht#Free_Books_by_Bob_Albrecht.
- Free books co-authored by Dave Moursund & Bob Sylwester. *IAE-pedia.* Retrieved 6/18/2018 from http://iae-pedia.org/IAE_Newsletter#Free_IAE_Books_by_David_Moursund_and_Robert_Sylwester.

Especially Popular Free Online IAE Books

- Moursund, D. (July, 2018). ***The Fourth R (Second Edition).*** *E*ugene, OR: Information Age Education. Read this Second Edition at http://iae-pedia.org/The_Fourth_R_(Second_Edition). Download the Microsoft Word file from http://i-a-e.org/downloads/free-ebooks-by-dave-moursund/307-the-fourth-r-second-edition.html. Download the PDF file from http://i-a-e.org/downloads/free-ebooks-by-dave-moursund/308-the-fourth-r-second-edition-1.html. Read the First Edition at http://iae-pedia.org/The_Fourth_R. Download the Microsoft Word file from http://i-a-e.org/downloads/free-ebooks-by-dave-moursund/289-the-fourth-r/file.html. Download the PDF file from http://i-a-e.org/downloads/free-ebooks-by-dave-moursund/290-the-fourth-r-1/file.html.
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Moursund's Collections of Quotations

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IAE-compiled Lists of Free Online Resources from a Wide Variety of Sources

Free Math Education Materials

See http://iae-pedia.org/Free_Math_Education_Videos. My 7/14/2018 Google search of the expression *free math education video* produced about 422 million results. This large number suggests to me that a person could spend their lifetime just looking at math videos. On my website I have listed a few that I found particularly interesting. As you browse the Web and find math videos that you think are particularly appropriate for use with your students and other children, I recommend that you *spread the word* to your friends and colleagues.

See http://iae- pedia.org/Free Math_Software. My 7/14/2018 Google search of the expression *free math software* produced about 313,000,000 results. I am particularly interested in such software, since it is closely related to the **4th R** aspects of math education. There is considerable value in being able to do certain math calculations in one's head, seeking either exact or approximate answers. This ties in closely with having good *number sense*. However, many of the real-world math problems that people solve nowadays require thousands, million, billions, trillions, or even more calculations. A fundamental component of a good math education is developing a repertoire of math problems that are relevant to one's interests and occupation and that are most effectively solved by use of a computer.

Free Science Education Software Materials

See http://iae-pedia.org/Free_Science_Software. Computers are now an integral component of learning and "doing" science. The Free Science Education Software document provides brief introductions to a number of sites that specialize in developing and disseminating software of particular use in K-12 education.

See http://iae-pedia.org/Free_Science_Education_Videos. My 7/14/2018 Google search of the expression *free science educational video* produced about 161 million results. I often watch such video material on PBS television. I am always amazed by the quality of the materials that are available free.

Free Open Content Libraries

See http://iae-pedia.org/Free_Open_Content_Libraries. The development of reading and writing more than 5,000 years ago made it possible and desirable to accumulate information in a form that could be preserved over many years and widely disseminated. Historically, such materials were stored in "hard copy" form. However, the development of photography, audio recordings, video recordings, and then electronic digital storage and retrieval have greatly changed the nature of libraries.

A number of the great libraries of the world are making good progress in digitizing their holdings. The totality of these materials that can be accessed online is still growing rapidly. It is now common to refer to the Web as the world's largest library. This makes me chuckle when I have a book or magazine in hand that is not stored on the Web. At that moment, the Web plus my book or magazine represent a library larger than the Web. On a grander scale, when you go into a library that contains many documents that are not on the Web, and then make use of both that library and the Web, you are making use of a library far larger than either of these two individual libraries.

Free and Open-source Software (FOSS)

See https://en.wikipedia.org/wiki/Free_and_open-source_software. My 7/14/2018 Google search of *free and open-source software* produced about 390 million results. Quoting from the Wikipedia site:

> **Free and open-source software** (**FOSS**) is software that can be classified as both free software and open-source software. That is, anyone is freely licensed to use, copy, study, and change the software in any way, and the source code is openly shared so that people are encouraged to voluntarily improve the design of the software. This is in contrast to proprietary software, where the software is under restrictive copyright and the source code is usually hidden from the users.
>
> The benefits of using FOSS can include decreased software costs, increased security and stability (especially in regard to malware), protecting privacy, education, and giving users more control over their own hardware. Free, open-source operating systems such as Linux and descendants of BSD are widely utilized today, powering millions of servers, desktops, smartphones (e.g. Android), and other devices. Free software licenses and open-source licenses are used by many software packages. The Free software

movement and the open-source software movement are online social movements behind widespread production and adoption of FOSS.

See http://iae-pedia.org/Free_Open_Source_Online_Databases. A database is a collection of information that is organized so that it can easily help to solve problems and accomplish tasks. Telephone directories and a dictionaries are databases. Over the years, printed telephone directories have seen less and less use, as more and more of such content is made available on the Web. A database may be as simple and short-lived as a handwritten shopping list, and as large as the Web. Yes, the World Wide Web is a database, and you certainly want all of your students to become experienced in making effective use of this database.

See http://iae-pedia.org/Free_Open_Source_Software_Packages. Quoting from the Free Software Foundation (FSF):

> Free software developers guarantee everyone equal rights to their programs; any user can study the source code, modify it, and share the program. By contrast, most software carries fine print that denies users these basic rights, leaving them susceptible to the whims of its owners and vulnerable to surveillance.

- The FSF provides critical infrastructure and funding for the GNU ("GNU's Not Unix!" project, the foundation of the popular GNU/Linux family of free operating systems and the keystone of the Internet.
- Our Campaigns Team creates educational materials about free software, convenes the yearly LibrePlanet conference and goes toe to toe against powerful interests that threaten computer user rights.
- Our Licensing & Compliance Lab defends freely licensed software from proprietary hoarding, advises on licensing issues, and certifies devices that Respect Your Freedom.

Free Educational Videos

See http://iae-pedia.org/Free_Educational_Videos.

Thomas Edison was one of the world's greatest inventors. However, some of his forecasts for the future now seem quite amusing. Here is one of my favorites:

"Books will soon be obsolete in the schools.... Scholars will soon be able to instruct through the eye. It is possible to touch every branch of human knowledge with the motion picture." (Statement by Thomas A. Edison, 1913.)

Today's children routinely use interactive computer educational and entertainment materials that (I assume) are far beyond Edison's wildest imaginations. The Free Educational Videos document contains brief discussions about and links to a large number of these materials.

Final Remarks

Most of the PreK-12 educational systems of the world have yet to comprehend and make effective use of the improvements that are possible by integrating the routine full use of the **4th R** of **R**easoning/Computational Thinking and Information and Communication

Technology (ICT) into the curriculum. You have heard the statement, “Where there's a will, there's a way.”

I can imagine an educational system in which every student is growing up with rapid voice, keyboard, and touch screen input to access the steadily growing accumulated knowledge of the human race. This world also contains artificially intelligent systems that can help in solving problems, accomplishing tasks, and answering questions.

Remember that whether one is keyboarding into a computer system, talking to a computer system, or tapping buttons to indicate choices to be sent to a computer system, **one is in communication with a machine.** The machine has a type of artificial intelligence, but it does not have human comprehension of a message. Thus, a “new” part of a good education is learning to communicate effectively with a non-human computer system. I certainly find this frustrating at times–especially when I want the computer to connect me with a human being!

As ICT capabilities continue to improve, students are becoming more skilled in using them at home and in other non-school locations. **It is increasingly imperative that our educational systems keep pace with and provide some leadership in what the students are learning on their own.**

What You Can Do

Reread the Final Remarks. A great many schools and students now have high-quality Web access that allows students to learn its capabilities and limitations as they apply the information they locate to each subject area they are studying. Students themselves, along with teachers, parents, and others, have the capability of making this happen right now. **I assume you are doing your part!**

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